

AN ECONOMIC STUDY OF PRESTRESSED  
CONCRETE

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CHARLES B. HOGAN

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AN ECONOMIC STUDY  
OF  
PRESTRESSED CONCRETE

Submitted to the Faculty of  
RENSSELAER POLYTECHNIC INSTITUTE  
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by  
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Thesis

#67

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MEMORANDUM

The purpose of this memorandum is to inform you of the results of the investigation conducted by the Special Agent in Charge of the New York Office, dated 10/10/54, regarding the activities of the [redacted] in the [redacted] area. The investigation has revealed that the [redacted] has been active in the [redacted] area, and that the [redacted] has been in contact with the [redacted] in the [redacted] area. The [redacted] has been found to be a member of the [redacted] and has been active in the [redacted] area. The [redacted] has been found to be a member of the [redacted] and has been active in the [redacted] area. The [redacted] has been found to be a member of the [redacted] and has been active in the [redacted] area.

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9. COMPLETION OF THE WORK

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## INTRODUCTION

The purpose of this thesis is to compare the cost of prestressed concrete structures with the cost of conventional structures and to determine if, and under what conditions, prestressed concrete compares favorably. This comparison is not all-inclusive because of time limitations. It is a start in a field previously undocumented, and it is hoped by the authors that the investigation will be continued and extended to other designs.

The investigations in this thesis include a comparison of fourteen simple rectangular beams, a small highway bridge, and a larger highway overpass bridge. The fourteen simple beams were chosen as a starting point because they represent an element found in many structures. Since it was impossible to investigate all the conceivable combinations of spans and loads, the fourteen were chosen as common ones encountered in practice. The small highway bridge was selected because of its simplicity and also because it was the first prestressed bridge completed in this country. The highway overpass bridge is a typical example of large bridges being constructed in considerable numbers by the highway departments of most states. The contract for this bridge has been awarded and the bridge will be a part of the New York Thruway.



Prestressed concrete is a relatively new method of bridge and building construction in the United States; however, it has been used to a considerable extent in circular tanks and piping. At the time of this writing, the only completed bridge of major proportion was the Walnut Lane Bridge in Philadelphia. This bridge was also the first project to be started in this country. A smaller bridge in Madison County, Tennessee, was begun after the Walnut Lane Bridge but was completed before it, thereby gaining the distinction of being the first prestressed concrete bridge completed in this country. The cost of the prestressed bridge in Madison County, Tennessee, is compared with a conventional design for the same site in Part II of this thesis.

Prior to its introduction in the United States, prestressed concrete had been used for some time in Europe (1)<sup>1</sup>. The supply of materials, especially steel, has always been critical in Europe, even more so during and after World War II. Since prestressed construction results in an economy of materials, it has been used extensively there (2). The European methods of prestressing entail the placing and stressing of individual wires or small groups of wires at one time. This results in considerable labor, however it is not a controlling factor because Europe has a large supply of cheap labor.

1. Numbers in parentheses refer to Reference numbers.



Prior to the late 1930's the American supply of iron ore was considered relatively inexhaustible. By relatively inexhaustible, it is meant that there was a plentiful supply for the next forty or fifty years, and within that period it was reasonably expected that new techniques would be developed which would make possible the use of impure iron deposits. The steel industry also expected to find new rich deposits during that period. The drain of reserves caused by World War II and the increased peacetime use have depleted the supply to the point that the Lake Superior deposit will be exhausted within the next ten to twelve years. A considerable amount of capital has been invested in research and successful methods have been developed to beneficiate the impure ores. The use of these methods, however, will entail a considerable increase in cost due to the additional processing (3). New deposits have recently been discovered in South America, and it is planned to use these deposits as much as possible in the future, thereby prolonging the life of the Lake Superior ranges. In an emergency, however, an enemy or a change of local government could deny us access to these ores. It is an accepted fact that prestressed concrete results in a considerable saving in steel. This being the case, prestressed concrete construction can and should play an important part in our future.



The supply of concrete itself has not been equal to the demand during the summer and fall months of each year since World War II. Its tremendously increased use in highway pavements has been one of the main causes of this shortage. In addition the heavy demand for cement by the construction industry during this period shows no sign of abatement, and it is anticipated that the shortage will be even more critical during the summer and fall of 1951.

It is the authors' opinion that the development of a very high strength single strand to replace the individual wires, common to European practice, by the John A. Roebling's Sons Co. will result in an economic utilization of labor in this country, despite the high level of wage rates. Although this strand requires a much larger jacking unit, this simplified method is considered a characteristic expression of American ingenuity and implementation.

Before prestressed construction can be economically utilized in this country, it must: 1. be accepted by the designing engineers who are reluctant to adopt radically new designs, and 2. be accepted by the contractors who are naturally hesitant to give realistic bids on the prestressing operation itself, because of their unfamiliarity with the work. The latter results in high bids even though the quantities of material are smaller, and consequently no economy is realized by the builder.





There is a distinct possibility that the material situation may become so critical that the use of prestressed construction may be imperative in order to conserve materials, even though it may not be the most economical in all applications.

There is a distinct possibility that the material  
attention has been paid to the fact of presentness  
construction may be indicative in order to conserve materials,  
even though it may not be the best economical in all applic-  
ations.

## PART I

## COMPARISON OF SIMPLE RECTANGULAR BEAMS

As is stated in the Introduction, it is impossible to investigate all the conceivable combinations of spans and loads; therefore, fourteen were chosen as common ones encountered in practice. The spans and loads are as follows:

<u>Span</u>	<u>Load</u>	<u>Span</u>	<u>Load</u>
20 feet	200 ppf	40 feet	100 ppf
"	300 "	"	200 "
"	400 "	"	300 "
"	500 "	"	400 "
30 feet	100 "	"	500 "
"	200 "		
"	300 "		
"	400 "		
"	500 "		

The quantities for each beam are 1, 10, 100 and 1000. The comparison will include: 1. quantities of materials, 2. labor cost, 3. material cost, and 4. total cost.

Conventional Design Procedure

In the conventional design the procedure and tables of the Reinforced Concrete Design Handbook were used exclusively. The allowable stresses were taken from ACI Standards - 1949. A depth to breadth ratio of 2 to 1 was used, as this ratio is considered to give the most economical section (4). The results of these design computations are given in Table I, page 19. Since there is no appreciable difference in the

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price of concrete in New York City, 3750 psi concrete was used to give a higher allowable diagonal tension stress and therefore eliminate stirrups.

### Prestressed Design Procedure

The prestressed design was based on a method developed by Mr. Fred J. Uziel, Staff Engineer, Preload Corporation, N. Y. Since the purpose of this thesis is an economic study, the details of the design procedure are not given. The results of the computations are given in Table II, page 22. For a complete presentation of the method, the reader is referred to Reference 5.

As with the conventional design, a depth to breadth ratio of 2 to 1 was used. In Mr. Uziel's method, a depth must be assumed. To eliminate trial and error in determining the depth in each case, a formula of Magnel's was used (6).

$$\frac{bD^2}{6} \geq \frac{M_a}{.775c + c_t}$$

$M_a$  = the moment due to the live load

$c$  = the permissible compressive stress in concrete

$c_t$  = the permissible tensile stress in concrete

$b$  = the breadth

$D$  = the depth

By setting  $b = \frac{D}{2}$  the only unknown is  $D$  and it can therefore be solved directly.

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The symbol "c" shown in the design table is defined in Mr. Uziel's method as the ratio of area of strand hole to the area of the section. The value of  $c = 2.5\%$  used in the design was chosen because it is a very conservative value. In all cases the actual ratio is much less than  $2.5\%$ .

At the time of this writing, no codes for prestressed design had been adopted. Since in prestressed design the entire section is considered to resist flexure, a 5000 psi concrete was used. The allowable stresses based on 5000 psi are tabulated in the design table.

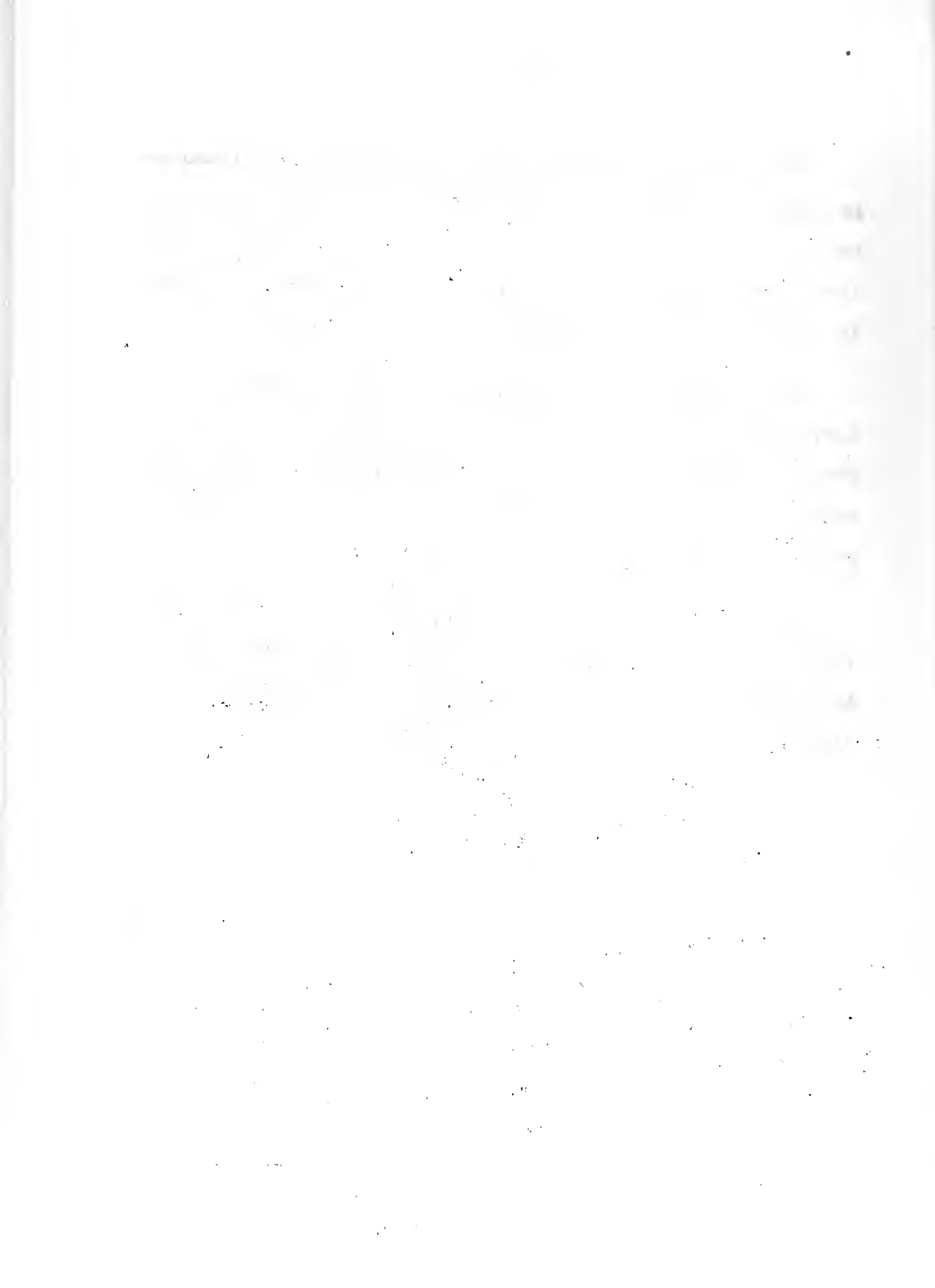
An allowable diagonal tension stress of  $3\%$  of  $f'_c$  or 150 psi is assumed. In the design table the computation of horizontal shear at the neutral axis, as a measure of diagonal tension, was based on  $v = \frac{3V}{2A}$ .

$v$  = intensity of horizontal shear in psi

$V$  = total shear due to applied loads and beam wt. in lbs

$A$  = total cross-sectional area in in.<sup>2</sup>

In all cases  $v$  was less than the allowable intensity of unit stress. There are two additional considerations which must be included if an exact solution is to be made for the maximum principal tensile stress. These are the shear force due to the curvature of the strand and the compressive stress in the end of the beam due to the stress in the strand. Since these two factors will reduce the value of the maximum





principal tensile stress below that calculated for  $v$  above, the results tabulated are conservative.

The size of the prestressed strand required is determined by the value of "P" in the Prestressed Design Table, page 23. With this value of "P" the cable size is selected from the Strand Physical Properties Table, page 24.

#### Basic Assumptions

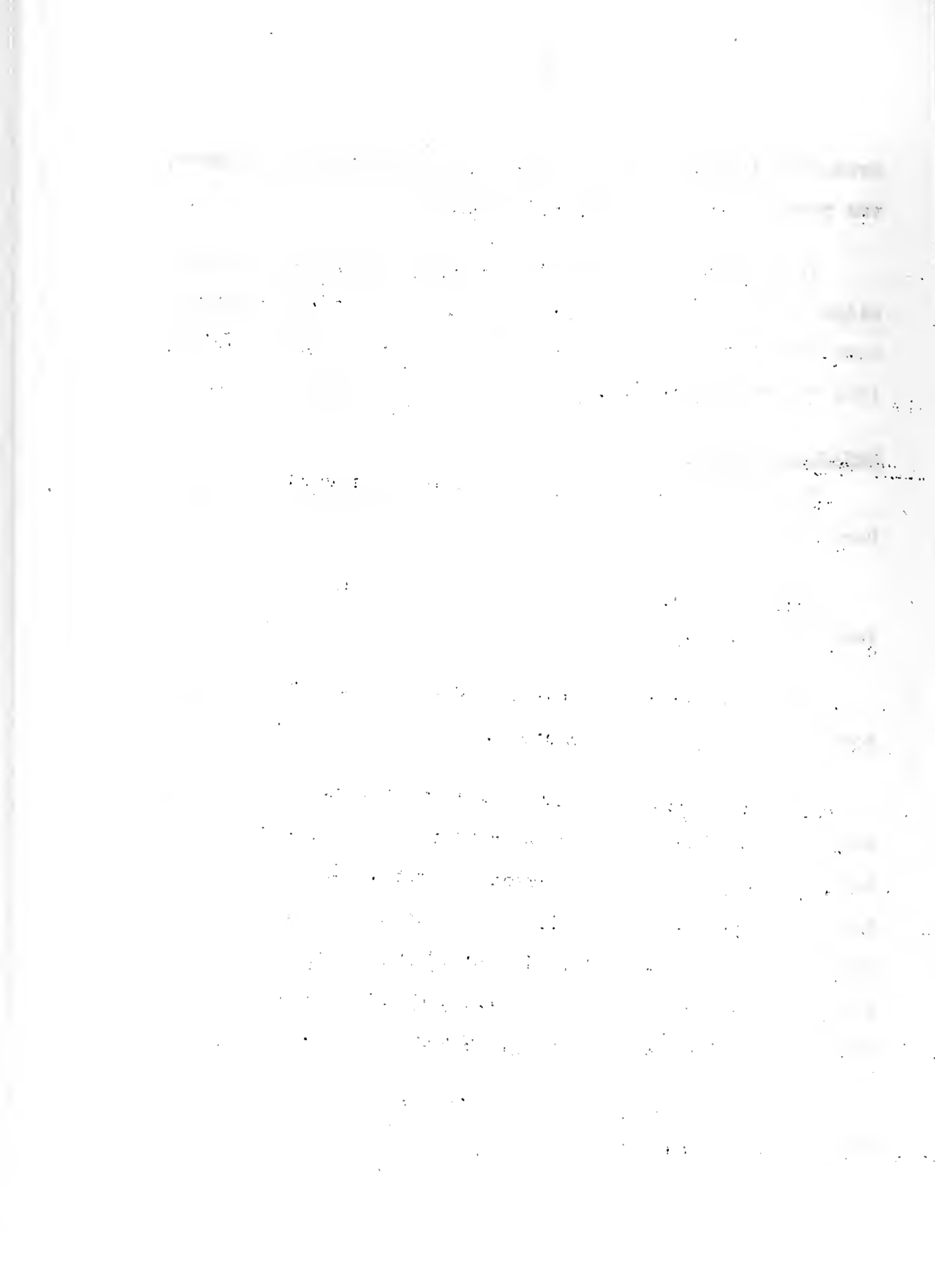
The plant is assumed to be set up expressly for each beam casting job.

One beam will be poured on the job site with one wood form by carpenters and common laborers.

Ten beams will be poured on the job site with two wood forms by carpenters and common laborers.

One hundred beams will be poured on a special site constructed or existing for this purpose with ten steel forms by carpenters, steel workers and common laborers. The forming operation itself will still be done by carpenters even though steel forms are used. The steel worker will place and tie the reinforcing bars in the conventional beams and the prestressing strands in the prestressed beams.

One thousand beams will be handled the same as one hundred except that fifty steel forms will be used.



The wood forms are plywood contact surfaces with 2x4 bracing 16" cc. For one beam the salvage value of the lumber is one-half its initial cost. For the ten beam job two wood forms are used and after five pourings each, the material has no salvage value.

The steel forms are fabricated for assembly and disassembly in lengths of approximately five feet. They are two-piece clamp type with open top. It is estimated that the life of this form is one-thousand pourings. This number of re-uses which is higher than claimed by manufacturers is used because the concrete is to be poured on an oiled concrete floor and not in place in a structure. Thus each pouring absorbs 1/1000 of the total cost of one form.

For the one and ten beam groups the hours of carpenter and common labor per 100 square feet of contact surface (SFCS) for each type of form was based on past estimates of conventional beams and columns in place in reinforced concrete buildings. This was the lowest estimate in hours given in a series of similar structures. Naturally the time required to erect and disassemble a beam in place would be much higher than doing the same work on the ground level with no scaffolding required and where working conditions are much more expedient. Therefore, instead of reducing this time, it is assumed that the extra time above that for the general



erecting, disassembling, and cleaning will be taken up in placing reinforcing bars, operating vibrators, cleaning the floor area, oiling the floor area, etc., and accomplishing other jobs which are not necessarily allowed in conventional work or which are done by other workers.

For the 100 and 1000 beam lots the steel placing would be done by structural iron workers. The amount of carpenter labor has been reduced proportionally to allow for this change. The placing of the forms, etc., is still done by the carpenters, even though the forms are of steel.

In order to be more specific the authors have used the wages for carpenters, structural iron workers, and common laborers in New York City as of January, 1951, as reported in Engineering News Record of January 11, 1951.

The average price of ready mix concrete in New York City in January, 1951, was used. The same price of ready mixed concrete was used for both the conventional and the prestressed beams, because of the high quality of aggregates available in that area. The concrete price is per cubic yard delivered and poured wherever the contractor desires.

Reinforcing bars will be purchased in lots over one ton and will be delivered bent, hooked, and ready for placing in



the beam. The price of the bars is that in January, 1951, as taken from the Engineering News Record of January 11, 1951.

Prestressing strands will be purchased in actual lengths required, ready for placing in the beam. The price is quoted by John A. Roebling's Sons Co. for January, 1951.

The bearing assembly for the prestressed beam consists of a flat plate with a hole just large enough to allow the male thread on the end socket to pass through. A cardboard tube will be placed around the socket and strand and held flush against the inside of the bearing plate by wire ties. The end around the strand will be stuffed with paper to prevent the concrete from running into the tube, thus preventing any contact between the socket and the concrete. The entire length of the strand is wrapped with heavy brown wrapping paper and tied with wire ties. This prevents the concrete from bonding to the strand, allowing the strand to elongate uniformly throughout its entire length during prestressing.

#### COMPUTATION OF BASIC UNITS AND BASIC UNIT COSTS

##### I. One and Ten Beams

###### A. Forms

One and ten beams are formed by plywood forms. It would be impossible to price each plywood form every time, so an average size beam was chosen and a hypothetical form





was made to arrive at a unit price per SFCS. This figure was then applied to all plywood forms. This form is three-sided, the top being left open. It is 5/8" plywood, studded with 2x4's, 16" cc.

1. Lumber Quantity for a Beam 1'w, 2'd, 30'L

Fir plywood 5/8" thick

$$\text{Sides } 2(2' \times 30') = 120 \text{ ft.}^2$$

$$\text{Bottom } (1' \times 30') = \underline{30 \text{ ft.}^2}$$

$$\text{Total SFCS} = 150 \text{ ft.}^2$$

2x4 studs 16" cc

Form braced on four sides

$$2(24"d + 4" + 4" \text{ lap}) = 64"$$

$$2(12"w + 4" + 4" \text{ lap}) = \underline{40"} \quad 104" \text{ per stud}$$

$$\text{No. of studs} = \frac{30 \times 12}{16} = 23$$

$$23 \times 104" = 2392" = 199.3' \text{ of } 2x4's$$

2. Lumber Prices

$$\text{Plywood @ } \$226.86/1000 \text{ ft.}^2$$

$$2x4's @ \$78.00/M.b.m.$$

3. Unit Cost of Form

$$\text{Plvwood} - \frac{\$226.86 \times 150 \text{ ft.}^2}{1000 \text{ ft.}^2} = \$34.029$$

$$2x4's - \frac{\$78 \times 199.3 \text{ ft.}}{1500 \text{ ft.}} = \underline{10.364}$$

$$\text{Total} = \$44.393$$

$$\text{Unit price} = \frac{\$44.393}{150 \text{ ft.}^2} = \$.2959/\text{ft.}^2$$



## B. Labor

The labor for one and ten beams is assumed on the basis of carpenters and common laborers.

### 1. Carpenters @ \$3.09/hr. (7)

Make up, erecting, and stripping

forms and place steel . . . . . 9 hrs/100 SFCS (12)

### 2. Common Laborers @ \$1.90/hr. (7)

Assisting carpenters, pouring

concrete, and oiling, cleaning

and moving forms . . . . . 6.5 hrs/100 SFCS  
(12)

## II. One Hundred and One Thousand Beams

### A. Forms

For one hundred and one thousand beams it is assumed that the contractor would buy fabricated steel forms. The steel forms would be used on two sides of the beam and would be set on a concrete floor which would be oiled to prevent bonding of the bottom of the beam to the floor. The cost as of January 1, 1950, was \$2.10 per SFCS. An increase in fabricated structural steel of 7.2% is figured for the year 1950, making the cost in January, 1951, \$2.25 per SFCS.

### B. Labor

The labor for one hundred and one thousand beams is assumed on the basis of structural iron workers, carpenters, and common laborers.

B. Labor

The labor for one and ten beams is assumed on the

basis of carpenters and common laborers.

1. Carpenter - \$3.00/hr. (7)

Make up, erecting, and stripping

forms and place steel . . . 9 hrs/100 sqft (1)

2. Common laborer - 1.90/hr. (7)

Assisting carpenters, pouring

concrete, and oiling, cleaning

and tying forms . . . 6.5 hrs/100 sqft (1)

III. One Hundred and One Thousand Forms

A. Forms

For one hundred and one thousand beams it is

assumed that the carpenter would be fabricating steel forms.

The steel is assumed to be used on the sides of the beam and

would be set up and dismantled after which would be tied to

prevent leakage of concrete from the beam to the floor. The

cost of fabricating steel forms is \$1.00 per sqft. An increase

in fabricating steel forms is \$1.25 in 1950 for the

year 1950, which is at an increase of 25% for 1950.

B. Labor

The labor for one hundred and one thousand beams is

assumed on the basis of carpenters and common laborers.

1. Carpenter - \$3.00/hr. (7)

1. Carpenters @ \$3.09/hr. (7)  
Erecting and stripping forms . . . 3.5 hrs. (12)
2. Common Laborers @ \$1.90/hr. (7)  
Erecting, stripping, cleaning  
and moving forms and pouring  
concrete . . . . . 2 hrs. (12)
3. Structural Iron Workers

a. Conventional Beams

An estimating handbook gives 16 hours of steel workers' labor per ton of steel for placing and tying in average in-place construction. This figure is reduced 25% to 12 hours because placing is being done on a slab on the ground, bars are all the same size in each beam, the bars are delivered bent and ready for placing, and no stirrups are required. The wage of structural iron workers in New York City in January, 1951, was \$3.25/hr. (7)

$$\text{Rate} = \frac{12 \text{ hr/ton} \times \$3.25/\text{hr}}{2000 \text{ lbs/ton}} = \$.0195/\text{lb.}$$

$$\text{Rate} = \$.0195/\text{lb.} = \$1.95/\text{cwt.}$$

b. Prestressed Beams

Ten minutes is allowed for two steel workers to place one strand and its two bearing assemblies. Five minutes is allowed for two men to accomplish



the prestressing operation. For the bridge in Madison County, Tennessee, the engineer stated that two adjacent strands in one beam were prestressed in one operation in five minutes.

Total time = 30 min./strand

Rate = \$3.25/hr.

### III. Reinforcing Steel for Conventional Beams

The price of reinforcing steel is of January, 1951 (7).

\$6.39 per 100 lb.

Delivery = .20 per 100 lb.

Bending = 1.75 per 100 lb.

Base Price = \$8.34 per 100 lb.

Base Price = \$.0834 per lb.

For 1",  $1\frac{1}{8}$ " and  $1\frac{1}{4}$ " bars, add \$.001 per lb. to base price if quantity is from 1 to 5 tons. For quantities less than one ton, add \$.0045 to base price.

Unit Cost:

1 to 5 tons = \$.0844 per lb.

less than 1 ton = \$.0879 per lb.

### IV. Prestressing Strands

The costs of the prestressing strands in each case are as listed in the estimate sheets and are as quoted by John A. Roebling's Sons Co. for January, 1951. The unit prices are based on a quantity of 100 assemblies but can be

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used for quantities ranging from 30 to 300. The same unit prices have been used for 1 and 10 assemblies on the assumption that the manufacturer has another order for the same size strand which will bring the total quantity within the range of 30 to 300. The same unit cost was used for 1000 assemblies, as a figure for this quantity was not available to the authors.

#### V. Bearing Assembly

The price per assembly is based on \$6.30 cwt for steel plate and the unit price for the tube which protects the socket is \$41.00 per 100 or \$370.00 per 1000. The labor for cutting the hole and sizing the plate is one-half hour of steelworker time at \$3.25 per hour.

used the following method: take 10 cc. of the  
 solution and add 10 cc. of water. It is then  
 clear that the solution is not saturated with the  
 salt. The solution is then added to the water  
 and the mixture is stirred. The mixture is then  
 allowed to stand for 24 hours. The mixture is  
 then filtered and the filtrate is evaporated to  
 dryness. The residue is then weighed.

The following method is used for the  
 determination of the amount of the  
 substance in the solution. The solution is  
 added to the water and the mixture is stirred.  
 The mixture is then allowed to stand for 24  
 hours. The mixture is then filtered and the  
 filtrate is evaporated to dryness. The residue  
 is then weighed.

CONVENTIONAL REINFORCED CONCRETE DESIGN NOTATIONS

L	Span of beam
$w_{LL}$	Live load
$f'_c$	Compressive strength of concrete at 28 days
$f_c$	Compressive unit stress in extreme fiber of concrete in flexure
K	$1/2 f_{ck}$
j	Ratio of distance between resultants of compressive and tensile stress to effective depth
$M_{LL}$	Live load moment
F	$\frac{bd^2}{12,000}$
b	Width of beam
D	Depth of beam
$w_{DL}$	Dead load
$w_T$	Dead load plus live load
$M_T$	Moment of dead and live load
d	Effective depth of beam
$A_s$	Area of steel
$M_R$	Resisting moment of concrete stresses
V	Total shear
v	Shearing stress
$\sum o$	Sum of perimeters of bars
u	Bond stress

# CONSTITUTIONAL HISTORY OF THE UNITED STATES

1	THE CONSTITUTION
2	THE FEDERAL GOVERNMENT
3	THE STATE GOVERNMENTS
4	THE JUDICIAL BRANCH
5	THE EXECUTIVE BRANCH
6	THE LEGISLATIVE BRANCH
7	THE BILL OF RIGHTS
8	THE AMENDMENTS
9	THE CONSTITUTIONAL CRISIS
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49	THE CONSTITUTIONAL HISTORY
50	THE CONSTITUTIONAL HISTORY

TABLE I  
CONVENTIONAL CONCRETE BEAM DATA



TABLE I

## CONVENTIONAL CONCRETE BEAM DATA (Cont'd.)

L ft	w <sub>LL</sub> ppf	Neg. Steel Check ft-k	V P	v psi	Allow. v psi	Diagonal Tension Check	Σ c in.	u psi	Allow. u psi	Steel Used	Clear Cover in.	Quantities	
												Steel P	Concrete cu. yd.
M <sub>R</sub> - M <sub>T</sub>													
				$\frac{V}{b \cdot d}$		$\frac{V}{\Sigma o \cdot d}$							
$v_{allow} - v$													
40	500	+16.0	17000	63.2	75	+11.8	18.0	45.7	188	4- $\frac{1}{8}$ " $\square$	1.88	728.0	3.74
40	400	+9.0	14200	62.2	75	+12.8	18.8	38.0	188	6-1" $\phi$	1.50	671.0	3.07
40	300	+27.0	11000	60.5	75	+14.5	13.5	44.8	188	3- $\frac{1}{8}$ " $\square$	1.50	546.0	2.42
40	200	+25.5	8300	51.0	75	+24.0	12.0	42.7	188	3-1" $\square$	1.50	420.0	2.16
40	100	+0.1	6080	46.5	75	+28.5	9.0	40.8	188	2- $\frac{1}{8}$ " $\square$	1.88	364.0	1.52
30	500	+0.3	10700	68.7	75	+6.3	10.0	68.7	188	2- $\frac{1}{4}$ " $\square$	1.88	344.4	1.58
30	400	-0.5	8700	65.7	75	+9.3	10.0	59.2	188	2- $\frac{1}{4}$ " $\square$	1.88	344.4	1.36
30	300	+1.4	6750	54.25	75	+20.8	9.0	54.2	188	2- $\frac{1}{8}$ " $\square$	1.50	276.0	1.11
30	200	+0.1	4875	53.7	75	+21.3	8.0	50.3	188	2-1" $\square$	1.50	217.5	0.93
30	100	+1.5	3080	41.3	75	+33.7	6.3	37.7	188	2-1" $\phi$	1.50	170.5	0.78
20	500	+3.7	6170	72.8	75	+2.2	6.3	80.7	188	2-1" $\phi$	1.50	117.0	0.58
20	400	+4.1	5095	64.7	75	+10.3	6.3	72.2	188	2-1" $\phi$	1.50	117.0	0.54
20	300	+1.85	3907	62.7	75	+12.3	4.5	83.7	188	1- $\frac{1}{8}$ " $\square$	1.50	95.5	0.40
20	200	+0.57	2625	58.0	75	+17.0	4.0	72.3	188	1-1" $\square$	1.50	74.3	0.31





PRESTRESSED CONCRETE DESIGN NOTATIONS

$L$	Span
$w_{LL}$	Live load
$f_c$	Allowable compressive stress at prestressing
$f'_c$	Allowable compressive stress under full load
$f_t$	Allowable tensile stress at prestressing
$f'_t$	Allowable tensile stress under full load
$M_A$	Live load moment
$n$	Coefficient of maximum prestress loss
$D$	Depth of section
$c$	Ratio of area of cable holes to area of section
$\Delta f_t$	Change in $f_t$ due to cable holes
$\Delta f_c$	Change in $f_c$ due to cable holes
$\Delta f'_t$	Change in $f'_t$ due to cable holes
$A$	Area of section
$b$	Breadth of section
$P$	Prestressing force
$a$	Distance from bottom of beam to cable
$a'$	Revised distance from bottom of beam to cable where the distance is less than 2.5"
$P'$	Revised prestressing force corresponding to $a'$
$f_b$	Allowable bearing pressure of bearing plate
$A_b$	Required area of bearing plate
$t_b$	Thickness of bearing plate

SECRET

1000

WILSON, J. H. & J. H. WILSON

ALLIANCE COMMUNITARIAN

11/10/1944

ALLOPHELE

1140 long road

CONFIDENTIAL - SECURITY INDEX - 100-1017900

Death of a Hero

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Chapman

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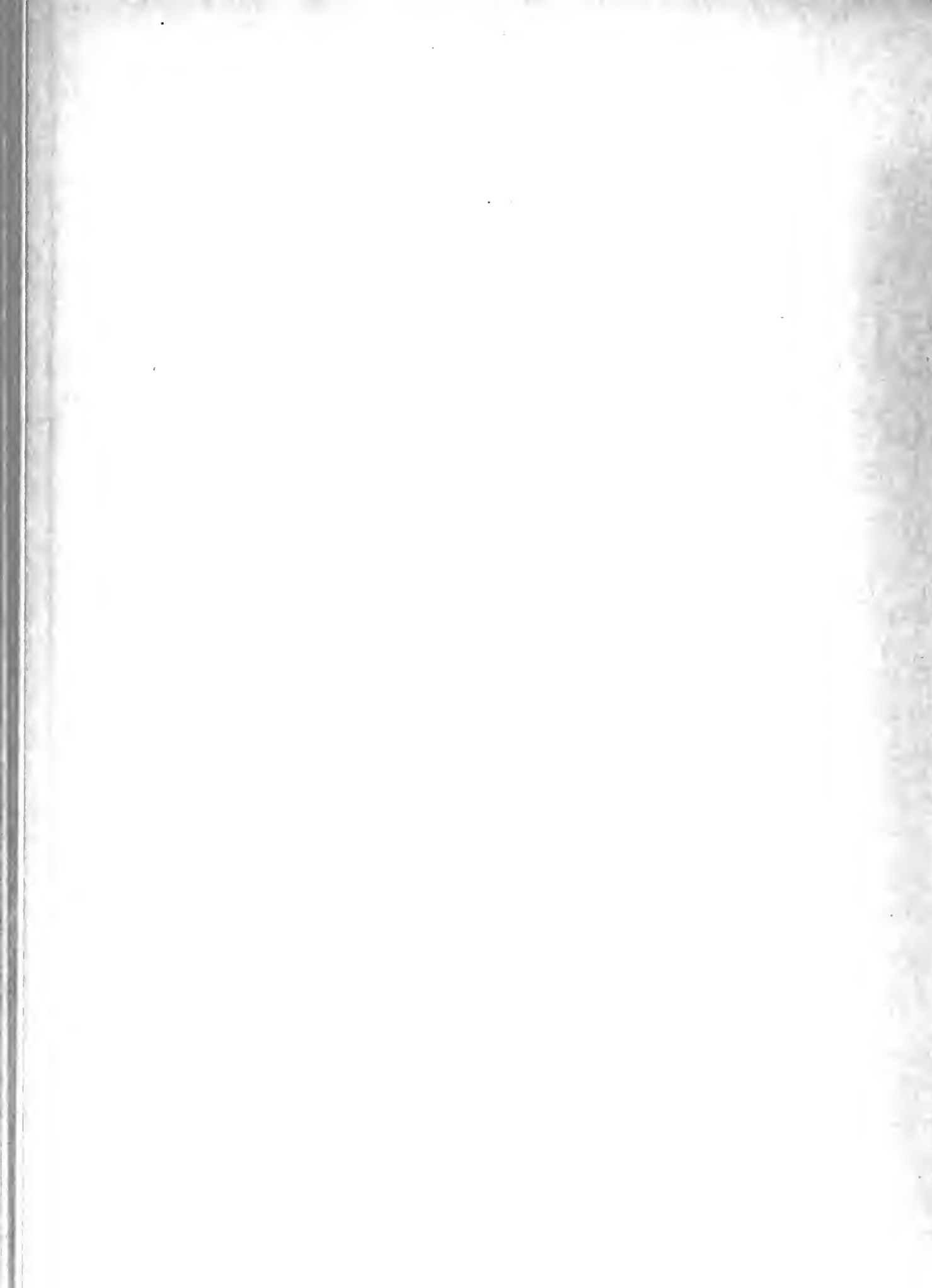
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TABLE II

## PRESTRESSED CONCRETE BEAM DATA

$L$ $f_t$	$\omega L$ $if$	$f_c$ $psi$	$f'_c$ $psi$	$f_t$ $psi$	$f'_t$ $psi$	$M_A$ $if$	$n$	$Q$	$\frac{.775f'_c + f_t}{6}$	$\frac{\omega L^2}{8}$	$\frac{L^3}{in^3}$	$D$ $in$	$k$	$g$	$g'$	$e$ $\%$	$\Delta f_t$ $psi$	$\Delta f_c$ $psi$	$\Delta f'_c$ $psi$
													$\frac{3\omega L^2}{4f'_c D}$	$\frac{f_t}{f'_c}$	$\frac{f'_t}{f'_c}$		$-\frac{2}{3}ek(2+k)f_c$	$-\frac{1}{3}e(1+k+k^2)f_c$	$+\frac{2}{3}ec(1-k^2)$
40	500	2200	2000	220	150	1,200,000	.85	321	7480	20.0	.341	.1	.068	2.5			-29.20	-107.0	+27.6
40	400	2200	2000	220	150	960,000	.85	321	6000	18.5	.369	.1	.068	2.5			-32.00	-110.0	+26.9
40	300	2200	2000	220	150	720,000	.85	321	4500	16.5	.413	.1	.068	2.5			-37.00	-116.0	+25.9
40	200	2200	2000	220	150	480,000	.85	321	3000	14.5	.471	.1	.068	2.5			-42.80	-124.0	+24.2
40	100	2200	2000	220	150	240,000	.85	321	1500	11.5	.543	.1	.068	2.5			-56.40	-143.0	+20.2
30	500	2200	2000	220	150	675,000	.85	321	5240	17.5	.217	.1	.068	2.5			-17.80	-92.9	+29.70
30	400	2200	2000	220	150	540,000	.85	321	4190	16.5	.232	.1	.068	2.5			-19.00	-94.3	+29.80
30	300	2200	2000	220	150	405,000	.85	321	3145	15.0	.256	.1	.068	2.5			-21.20	-97.0	+29.15
30	200	2200	2000	220	150	270,000	.85	321	2020	12.0	.295	.1	.068	2.5			-24.80	-100.7	+28.45
30	100	2200	2000	220	150	135,000	.85	321	842	9.5	.403	.1	.068	2.5			-35.60	-114.8	+26.10
20	500	2200	2000	220	150	300,000	.85	321	1940	12.5	.136	.1	.068	2.5			-10.68	-84.8	+30.30
20	400	2200	2000	220	150	240,000	.85	321	1553	11.5	.148	.1	.068	2.5			-11.68	-86.0	+30.53
20	300	2200	2000	220	150	180,000	.85	321	1125	10.5	.163	.1	.068	2.5			-12.90	-87.2	+30.40
20	200	2200	2000	220	150	120,000	.85	321	750	9.5	.180	.1	.068	2.5			-14.40	-88.9	+30.2



PRESTRESSED CONCRETE BEAM DATA (cont'd.)

L	w <sub>LL</sub>	ft	Revised		k	g	g'	A	b	P	a	a'	P'	Strand	f <sub>b</sub>	A <sub>b</sub>	t <sub>b</sub>	Plate	Section	Conc.	
			f <sub>ci</sub>	f' <sub>ti</sub>																	
			f <sub>ci</sub>	f' <sub>ti</sub>	psi			ft <sup>2</sup>	in	p	in	in	p		psi	in. <sup>2</sup>	in.	Size	b	D	cu. yd
			$f_c - \Delta f_c \quad f_c - \Delta f_c \quad f_c - \Delta f_c \quad \frac{3uL^2}{4t_e D} \quad \frac{f_{t1}}{f_{ci}} \quad \frac{f'_{t1}}{f_{ci}}$																		
40	500	20930	140.2	177.6	.359	.092	.084	1.340	10.0	190,000	3.37	-	-	2-1 1/4"	2750	69.1	3/4	10x20	10.0	20.0	2.06
40	400	20930	132.0	176.9	.389	.090	.085	1.190	9.5	167,500	2.91	-	-	1-1 5/8"	2750	60.8	3/4	9 1/2x10	9.5	19.5	1.90
40	300	2024.0	123.0	175.9	.436	.089	.084	1.000	9.0	141,500	2.34	2.50	144,500	1-1 1/16"	2750	51.5	1/2	9x9	9.0	16.5	1.53
40	200	2096.0	117.2	174.1	.492	.085	.084	.712	8.0	110,000	1.75	2.50	115,000	1-1 3/8"	2750	40.0	1/2	8x8	8.0	14.5	1.20
40	100	2057.0	103.6	170.2	.635	.080	.083	.507	6.5	70,500	0.85	2.50	92,000	1-1 1/4"	2750	25.6	1/2	6 1/2x6 1/2	6.5	11.5	0.77
30	500	2107.1	202.2	177.7	.229	.096	.085	.848	7.0	116,200	3.73	-	-	1-1 3/8"	2750	42.3	1/2	7x7	7.0	17.5	0.79
30	400	2105.7	201.0	179.2	.243	.096	.085	.717	6.5	101,900	3.38	-	-	1-1 5/16"	2750	37.1	1/2	6 1/2x6 1/2	6.5	16.5	0.83
30	300	2103.0	198.8	179.2	.268	.094	.085	.597	6.0	85,700	3.00	-	-	1-1 3/16"	2750	31.2	1/2	6x6	6.0	15.0	0.70
30	200	2094.3	195.2	178.5	.309	.093	.085	.464	5.5	68,000	3.64	-	-	1-1 1/16"	2750	24.7	1/2	5 1/2x6	5.5	13.0	0.59
30	100	2085.2	184.4	176.1	.425	.089	.085	.325	5.0	45,100	1.38	2.63	60,150	1-1"	2750	16.4	1/2	5x5	5.0	9.5	0.39
20	500	2115.0	209.3	180.3	.141	.099	.085	.517	6.0	71,500	3.05	-	-	1-1 1/8"	2750	26.0	1/2	6x6	6.0	12.5	0.39
20	400	2114.0	208.3	180.5	.154	.099	.085	.452	6.0	65,700	4.26	-	-	1-1 1/16"	2750	23.9	1/2	6x6	6.0	11.5	0.36
20	300	2112.8	209.1	180.4	.169	.099	.086	.373	5.5	54,800	2.50	-	-	1-1"	2750	19.9	1/2	5 1/2x6	5.5	10.5	0.30
20	200	2111.1	205.6	180.2	.187	.097	.085	.274	4.5	40,700	2.20	-	-	1-1"	2750	14.8	1/2	4 1/2x5	4.5	9.5	0.22



## JOHN A. ROEBLING'S SONS COMPANY

BRIDGE DIVISION

TRENTON, NEW JERSEY

SUBJECT: ~~PRESTRESSED-CONCRETE STRAND~~  
PHYSICAL PROPERTIES

Dia. (In.)	Wgt. per Ft. (Lb.)	Area (Sq. In.)	Min. Guarant- eed Ultimate Strength (Lb.)	Design Load (105,000 psi) (Lb.)	Tensioning Load (120,000 psi) (Lb.)
0.600	0.737	0.215	46,000	22,500	26,000
1	2.00	0.577	122,000	60,500	69,500
1-1/16	2.30	0.663	138,000	69,500	79,500
1-1/8	2.61	0.751	156,000	79,000	90,000
1-3/16	2.92	0.843	172,000	88,500	101,000
1-1/4	3.22	0.931	192,000	98,000	111,500
1-5/16	3.58	1.04	212,000	109,500	125,000
1-3/8	3.89	1.12	232,000	117,500	134,500
1-7/16	4.29	1.24	252,000	130,500	149,000
1-1/2	4.70	1.36	276,000	143,000	163,500
1-9/16	5.11	1.48	300,000	155,500	177,500
1-5/8	5.52	1.60	324,000	168,000	192,000

JH:lsk:dya  
11-17-50





COST ESTIMATE SHEETS FOR CONVENTIONAL  
AND PRESTRESSED BEAMS

The following pages, 26 through 81, are the sheets on which the costs of the fourteen conventional and fourteen prestressed beams are estimated for the quantities of 1, 10, 100 and 1000 beams.

AMERICAN AIR FORCE JOURNAL

RESEARCH REPORT

The following report is submitted to the American Air Force Journal, and is the property of the American Air Force Journal. It is not to be used for any other purpose without the permission of the American Air Force Journal.

Length 20' Load 200 ppf Section 12.5" x 5" Cu Yds Concrete .309 Lbs Reinforced Steel 74.3

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST			COST ALLOTTED	
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams	
Material									
Plywood Forms	S.F.C.S.	\$ .296	50	100	\$14.80	\$29.60	\$ 7.40	\$ 29.60	
Reinforcing Bars	Pound	\$ .0879	74.3	743	6.54	65.40	6.54	65.40	
Ready Mix Concrete	Cu. Yd.	\$11.15	.309	3.09	3.45	34.45	3.45	34.45	
Total-Mat'l.							\$17.39	\$129.45	
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies				
Labor					1 Form	2 Forms			
Carpenter	Hour	9	\$3.09	.50	1	10	\$13.90	\$139.00	
Common Labor	Hour	6.5	1.90	.50	1	10	6.18	61.75	
Total-Labor							\$19.68	\$196.75	
TOTAL							\$36.97	\$325.20	



COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

Length 20' Load 200 ppf Section 9.5" x 4.5" Cu Yds Concrete 0.22 Strand 1-1"

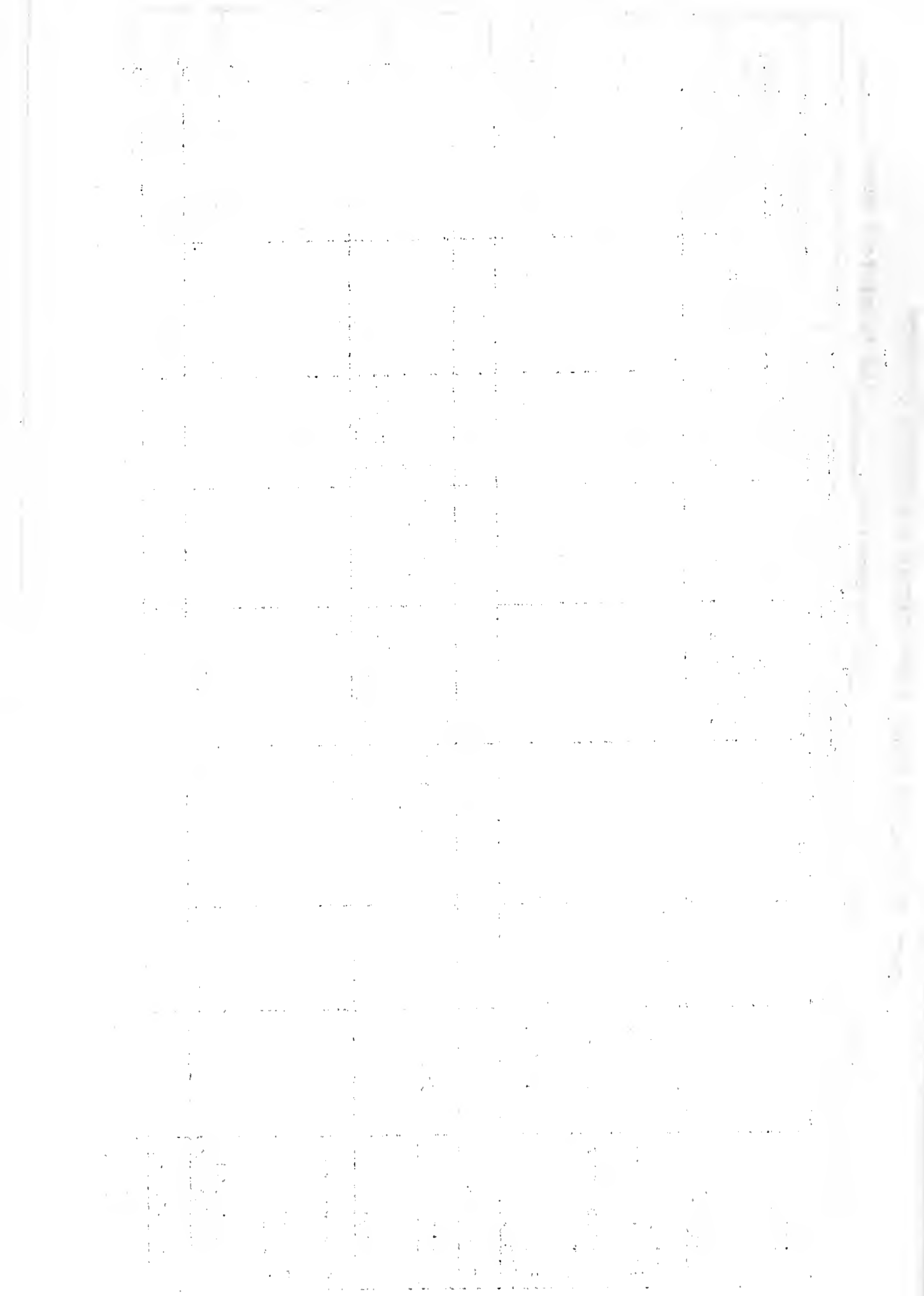
ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST			COST ALLOWED	
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams	
Material									
Flywood Forms	S.F.C.S.	\$ .296	39.20	78.40	\$11.60	\$23.20	\$ 5.80	\$ 23.20	
Strand							40.50	405.00	
Bearing Assembly							2.42	24.20	
Ready Mix Concrete	Cu. Yd.	\$11.15	0.22	2.2			2.46	24.60	
Total-Mat'l.							\$51.18	\$477.00	
ITEM									
Labor	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies				
					1 Form	2 Forms			
Carpenter	Hour	9	\$3.09	.392	1	10	\$10.90	\$109.00	
Common Labor	Hour	6.5	\$1.90	.392	1	10	4.83	48.30	
Total-Labor							\$15.73	\$157.30	
TOTAL							\$66.91	\$634.30	



COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

Length 20' Load 200 ppf Section 12.5"x15" Cu Yds Concrete .309 Lbs Reinforced Steel 74.3

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	400	2,000	\$900.00	\$4500.00	\$ 9.00	\$ 90.00
Reinforcing Bars	Pound	\$ .0844	7,430	74,300	-	-	627.00	6,271.00
Ready Mix Concrete	Cu. Yd.	\$11.15	30.9	309	-	-	344.50	3,445.00
Total-Mat'l.							\$ 980.50	\$ 9,806.00
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams		
Labor								
Carpenters	Hour	\$3.09	3.5	.4	-	-	\$ 432.00	\$ 4,320.00
Common Labor	Hour	\$1.90	2	.4	-	-	152.00	1,520.00
Structural Iron Worker	Cwt. of Steel	\$1.95	-	-	74.3	743.0	144.90	1,449.00
Total-Labor							\$ 728.90	\$ 7,289.00
TOTAL							\$1,709.40	\$17,095.00





# COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 20' Load 200 ppf Section 9.5"x4.5" Cu Yds Concrete 0.22 Strand 1-1"

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	317	1585	\$714.00	\$3570.00	\$ 7.14	\$ 71.40
Strand							4,050.00	40,500.00
Bearing Assembly							242.00	2,390.00
Ready Mix Concrete	Cu. Yd.	\$11.15	22	220			246.00	2,460.00
Total-Mat'l.							\$4,545.14	\$45,421.40
ITEM								
Labor	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	No. Units per Beam			
Carpenters	Hour	\$3.09	3.5	.317			\$ 342.50	\$ 3,425.00
Common Labor	Hour	\$1.90	2	.317			120.30	1,203.00
Structural Iron Worker	Hour	\$3.25			1/2		162.50	1,625.00
Total-Labor							\$ 625.30	\$ 6,253.00
TOTAL							\$5,170.44	\$51,674.40



COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

Length	Load	Cu	Yds Concrete	Lbs Reinforced Steel
20'	300 wpf	Section 14.5"x6"	.447	95.5

\$21.91	\$168.32
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TOTAL



# COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

31

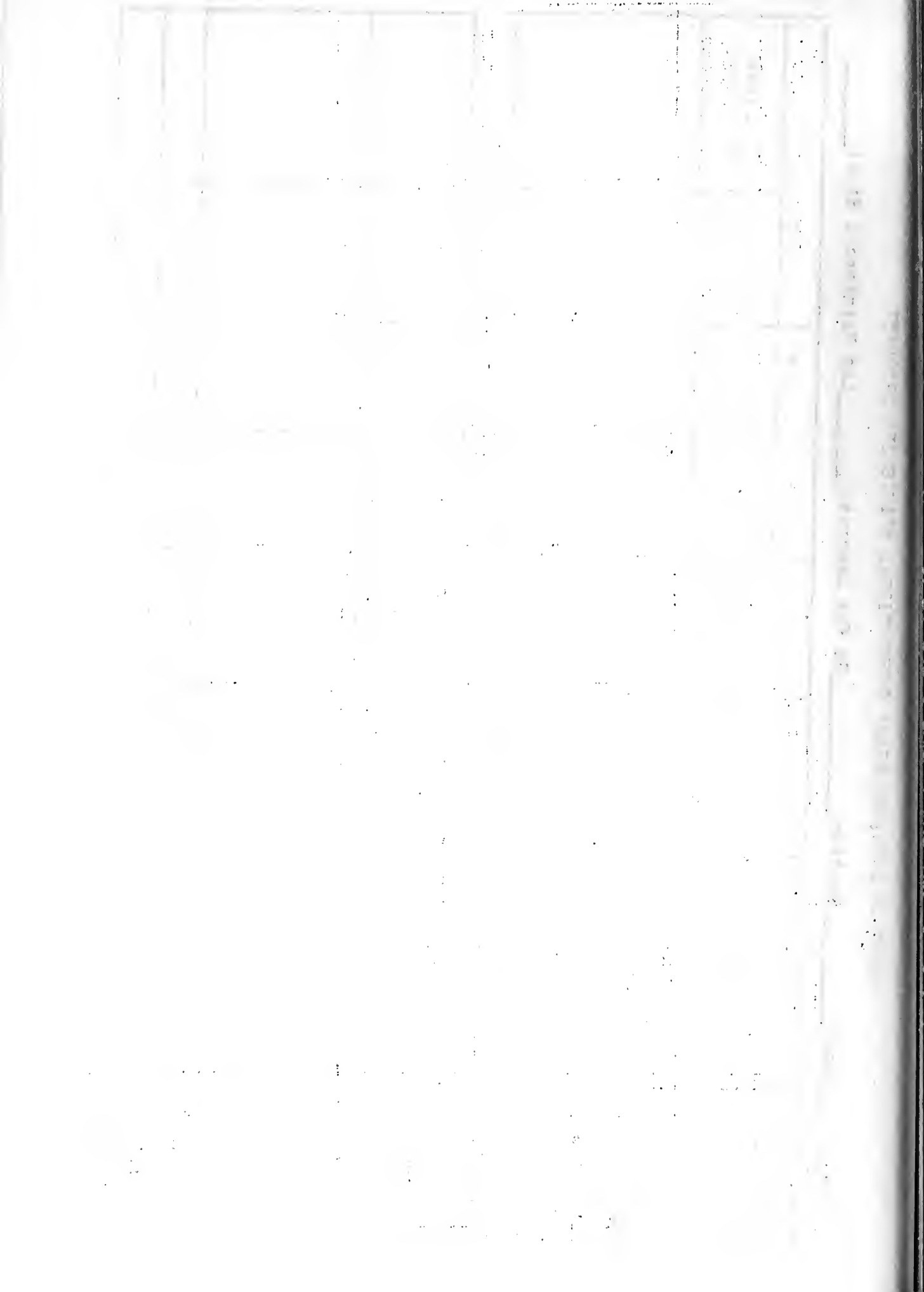
Length 20' Load 300 ppf Section 10.5"x5.5" Cu Yds Concrete 0.30 Strand 1-1"

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST			COST ALLOWED	
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams	
Material									
Flywood Forms	S.F.C.S.	\$ .296	44.2	88.4	\$13.10	\$26.20	\$ 6.55	\$ 26.20	
Strand							40.50	405.00	
Bearing Assembly							2.63	26.30	
Ready Mix Concrete	Cu. Yd.	\$11.15	0.30	3.0			3.35	33.50	
Total-Mat'l.							\$53.03	\$491.00	
ITEM									
Labor	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies				
					1 Form	2 Forms			
Carpenter	Hour	9	\$3.09	.442	1	10	\$12.29	\$122.90	
Common Labor	Hour	6.5	\$1.90	.442	1	10	5.46	54.60	
Total-Labor							\$17.75	\$177.50	
TOTAL							\$70.78	\$668.50	



Length 20' Load 300 ppf Section 14.5"x6" Cu Yds Concrete .447 Lbs Reinforced Steel 95.5

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	483.2	2,416	\$1087.00	\$5436.00	\$ 10.87	\$ 106.70
Reinforcing Bars	Pound	4.84	9,550	95,500	-	-	806.00	8,060.00
Ready Mix Concrete	Cu. Yd.	\$11.15	41.7	447	-	-	498.41	4,984.10
Total-Mat'l.							\$1,315.28	\$13,152.80
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams		
Labor								
Carpenters	Hour	\$3.09	3.5	.483	-	-	\$ 522.00	\$ 5,220.00
Common Labor	Hour	\$1.90	2	.483	-	-	183.54	1,835.40
Structural Iron Worker	Cwt. of steel	\$1.95	-	-	95.5	955	187.20	1,872.00
Total-Labor							\$ 892.74	\$ 8,927.40
TOTAL							\$2,208.02	\$22,080.20





# COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 20' Load 300 ppf Section 10.5"x5.5" Cu Yds Concrete 0.30 Strand 1-1"

33

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased steel Forms	S.F.C.S. per form	\$2.25	350	1750	\$787.00	\$3935.00	\$ 7.87	\$ 78.70
Strand							4,050.00	40,500.00
Bearing Assembly							263.00	2,600.00
Ready Mix Concrete	Cu. Yd.	\$11.15	30	300			335.00	3,350.00
Total-Mat'l.							\$4,655.87	\$46,528.70
LABOR								
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	No. Units per Beam			
Carpenters	Hour	\$3.09	3.5	.35			\$ 378.00	\$ 3,780.00
Common Labor	Hour	\$1.90	2	.35			133.00	1,330.00
Structural Iron Worker	Hour	\$3.25			1/2		162.50	1,625.00
Total-Labor							\$ 673.50	\$ 6,735.00
TOTAL							\$5,329.37	\$53,263.70



# COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

Length 20' Load 400 ppf Section 15" x 7" Cu Yds Concrete .54 Lbs Reinforced Steel 117

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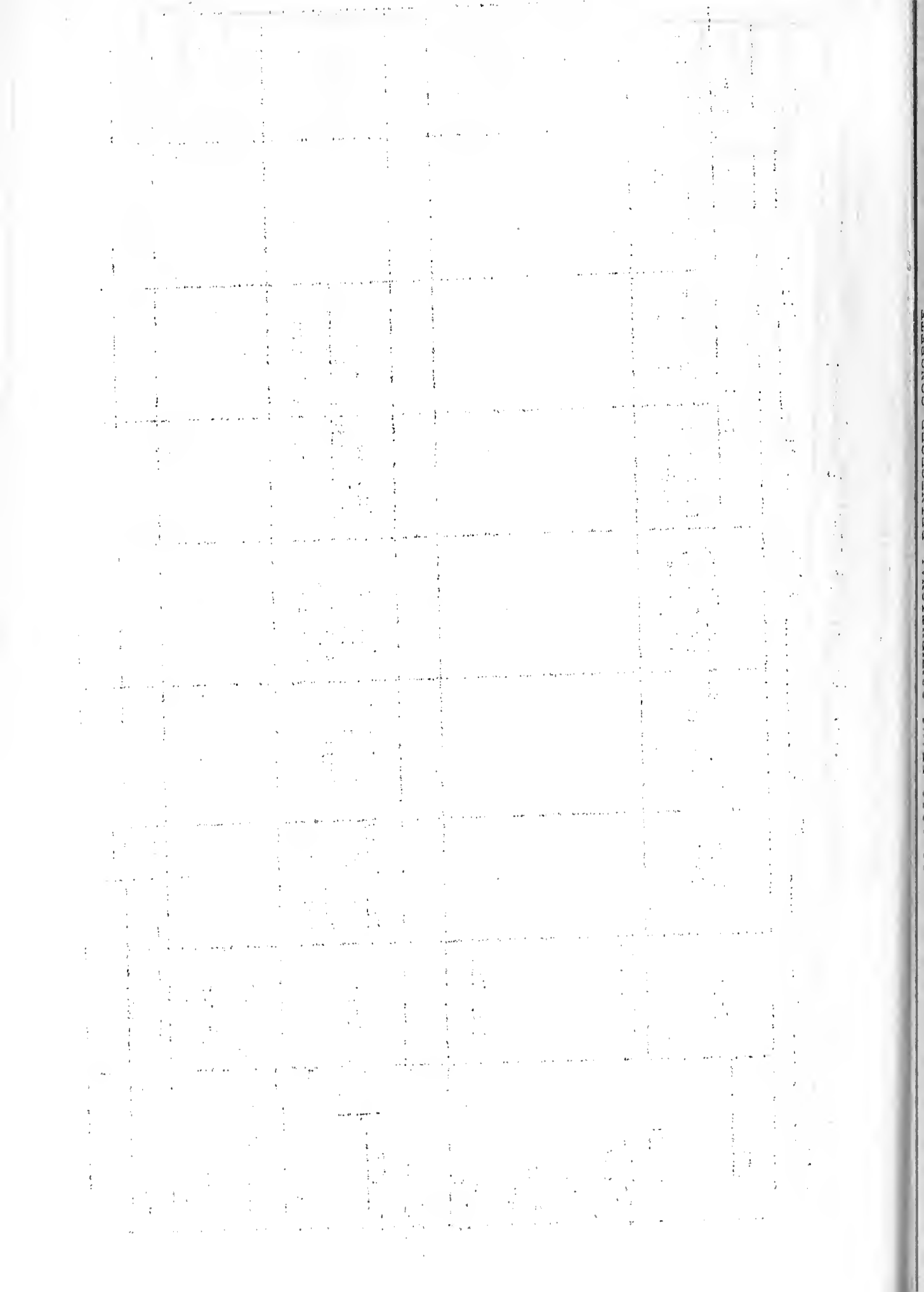
ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST		COST ALLOWED	
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	\$ .296	61.66	123.32	\$18.25	\$36.50	\$ 9.13	\$ 36.50
Reinforcing Bars	Pound	\$ .0879	117	1170	-	-	10.28	102.80
Ready Mix Concrete	Cu. Yd.	\$11.15	.54	5.40	-	-	6.02	60.20
Total-Mat'l.							\$25.43	\$199.50
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies			
Labor					1 Form	2 Forms		
Carpenter	Hour	9	\$7.09	.62	1	10	\$17.26	\$172.60
Common Labor	Hour	6.5	\$1.90	.62	1	10	7.66	76.60
Total-Labor							\$24.92	\$249.20
TOTAL							\$50.35	\$448.70



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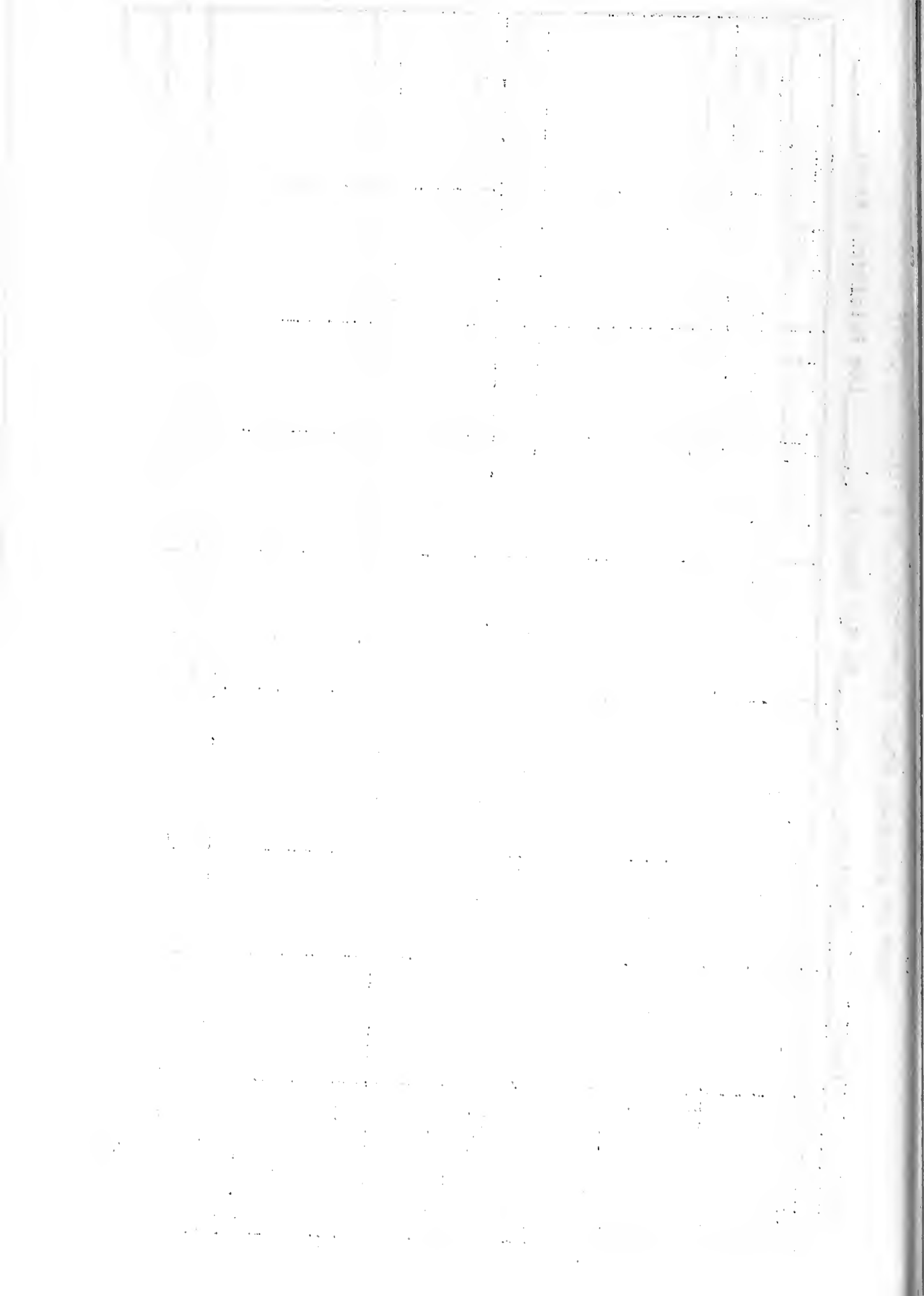
Length 20' Load 400 ppf Section 11.5"x6" Cu Yds Concrete 0.36 Strand 1-1 $\frac{1}{16}$ "

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST			COST ALLOWED
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams
Material								
Flywood Forms	S.F.C.S.	\$2.296	48.4	96.8	\$14.30	\$28.60	\$ 7.15	\$ 28.60
Strand							73.60	736.00
Bearing Assembly							2.68	26.80
Ready Mix Concrete	Cu. Yd.	\$11.15	0.36	3.6			4.02	40.20
Total-Mat'l.							\$ 87.45	\$ 831.60
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies			
Labor					1 Form	2 Forms		
Carpenter	Hour	9	\$3.09	.484	1	10	\$ 13.45	\$ 134.50
Common Labor	Hour	6.5	\$1.90	.484	1	10	5.97	59.70
Total-Labor							\$ 19.42	\$ 194.20
TOTAL							\$106.87	\$1,025.80



Length 20' Load 400 ppf Section 15" x 7" Cu Yds Concrete .54 Lbs Reinforced Steel 117

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	500	2,500	\$1125.00	\$5625.00	\$ 11.25	\$ 112.50
Reinforcing Bars	Pound	\$.0844	11,700	117,000	-	-	987.50	9,875.00
Ready Mix Concrete	Cu. Yd.	\$11.15	54	540	-	-	602.10	6,021.00
Total-Mat'l.							\$1,600.85	\$16,008.50
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cmt. of Steel for 100 Beams	Cmt. of Steel for 1000 Beams		
Labor								
Carpenters	Hour	\$3.09	3.5	.5	-	-	\$ 540.00	\$ 5,400.00
Common Labor	Hour	\$1.90	2	.5	-	-	190.00	1,900.00
Structural Iron Worker	Cvt. of Steel	\$1.95	-	-	117	1170	228.00	2,280.00
Total-Labor							\$ 958.00	\$ 9,580.00
TOTAL							\$2,558.85	\$25,588.50





COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 20' Load 400 ppf Section 11.5"x6" Cu Yds Concrete 0.36 Strand 1-1 1/16"

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	383.5	1917.5	\$862.00	\$4310.00	\$ 8.62	\$ 86.20
Strand							7,360.00	73,600.00
Bearing Assembly							268.00	2,650.00
Ready Mix Concrete	Cu. Yd.	\$11.15	36.0	360.0			402.00	4,020.00
Total-Mat'l.							\$8,038.62	\$80,356.20
ITEM								
Labor					No. Units per Beam			
Carpenters	Hour	\$3.09	3.5	.3835			\$ 414.00	\$ 4,140.00
Common Labor	Hour	\$1.90	2	.3835			145.80	1,458.00
Structural Iron Worker	Hour	\$3.25			1/2		162.50	1,625.00
Total-Labor							\$ 722.30	\$ 7,223.00
TOTAL							\$8,760.92	\$87,579.20

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	COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE		
Length	Load	Section	
20'	500	16" x 7"	Cu Yds Concrete .576 Lbs Reinforced Steel 117

38

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST			COST ALLOWED	
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams	
Material									
Plywood Forms	S.F.C.S.	\$ .296	65	130	\$19.24	\$38.48	\$ 9.62	\$ 38.48	
Reinforcing Bars	Pound	\$ .0879	117	1170	-	-	10.28	102.80	
Ready Mix Concrete	Cu. Yd.	\$11.15	.576	5.76	-	-	6.42	64.22	
Total-Mat'l.							\$26.32	\$205.50	
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies				
Labor					1 Form	2 Forms			
Carpenter	Hour	9	\$3.09	.65	1	10	\$18.07	\$180.70	
Common Labor	Hour	6.5	\$1.90	.65	1	10	8.03	80.30	
Total-Labor							\$26.10	\$261.00	
TOTAL							\$52.42	\$466.50	

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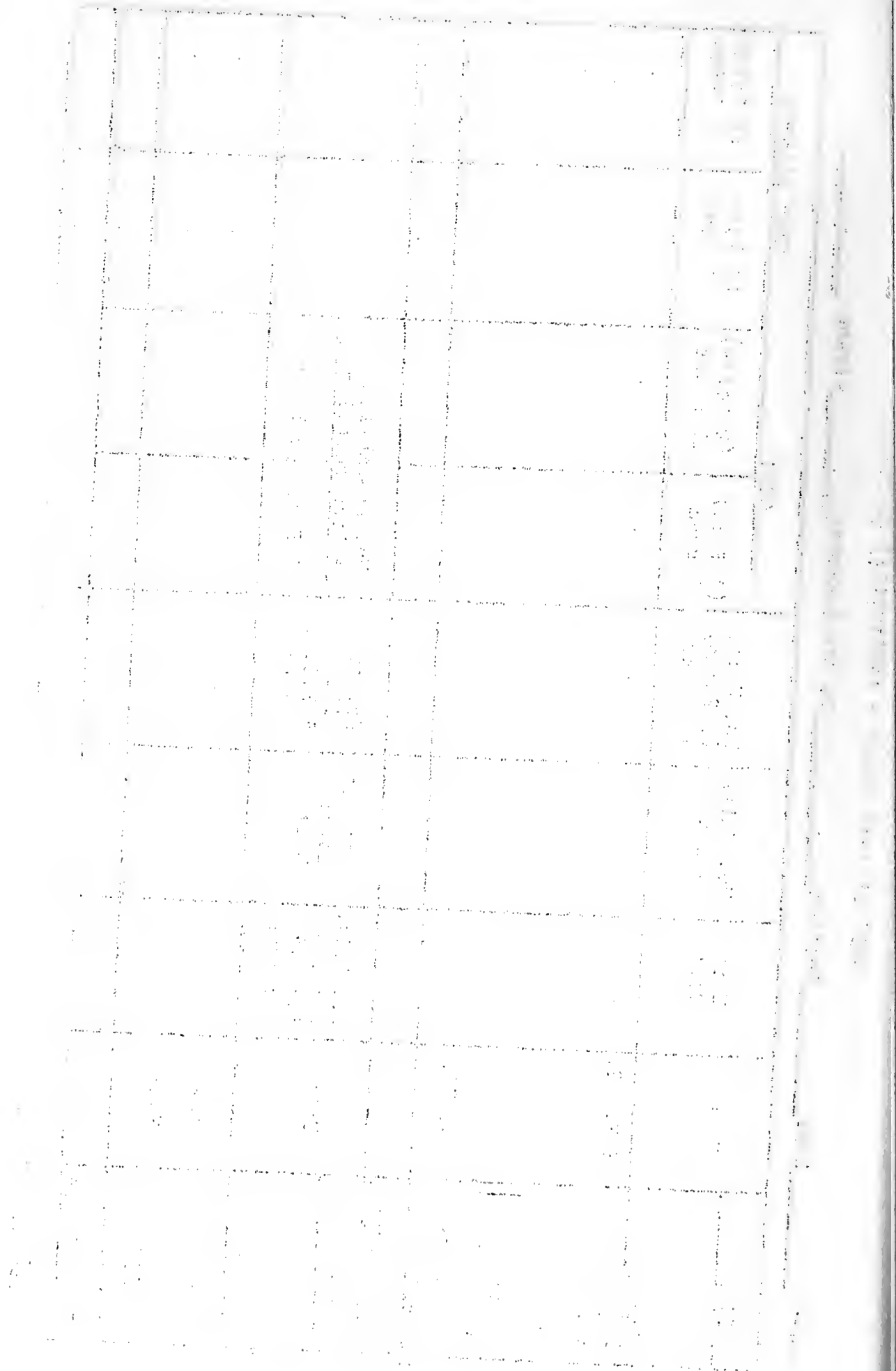
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# COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

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Length 20' Load 500 ppf Section 12.5"x6" Cu Yds Concrete 0.39 Strand 1-1 1/8"

ITEM		Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST			COST ALLOWED	
						(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams	
Material										
Plywood Forms	S.F.C.S.		\$ .296	51.7	103.4	\$15.30	\$30.60	\$ 7.65	\$ 30.60	
Strand								78.45	784.50	
Bearing Assembly								2.68	26.80	
Ready Mix Concrete	Cu. Yd.		\$11.15	0.39	3.90			4.35	43.50	
Total-Mat'l.								\$ 93.13	\$ 885.40	
ITEM		Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies				
						1 Form	2 Forms			
Labor										
Carpenter	Hour	9		\$3.09	.517	1	10	\$ 14.39	\$ 143.90	
Common Labor	Hour	6.5		\$1.90	.517	1	10	6.38	63.80	
Total-Labor								\$ 20.77	\$ 207.70	
TOTAL								\$113.90	\$1,093.10	



# COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

40

Length 20' Load 500 ppf Section 16" x 7" Cu Yds Concrete .576 Lbs Reinforced Steel 117

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	534	2670	\$1201.50	\$6007.50	\$ 12.02	\$ 120.20
Reinforcing Bars	Pound	\$1.0644	11,700	117,000	-	-	987.50	9,875.00
Ready Mix Concrete	Cu. Yd.	\$11.15	57.6	576	-	-	642.24	6,422.40
Total-Mat'l.							\$1,641.76	\$16,417.60
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams		
Labor								
Carpenters	Hour	\$3.09	3.5	.534	-	-	\$ 576.00	\$ 5,760.00
Common Labor	Hour	\$1.90	2	.534	-	-	202.92	2,029.20
Structural Iron Worker	Cwt. of Steel	\$1.95	-	-	117	1170	228.00	2,280.00
Total-Labor							\$1,006.92	\$10,069.20
TOTAL							\$2,648.68	\$26,486.80

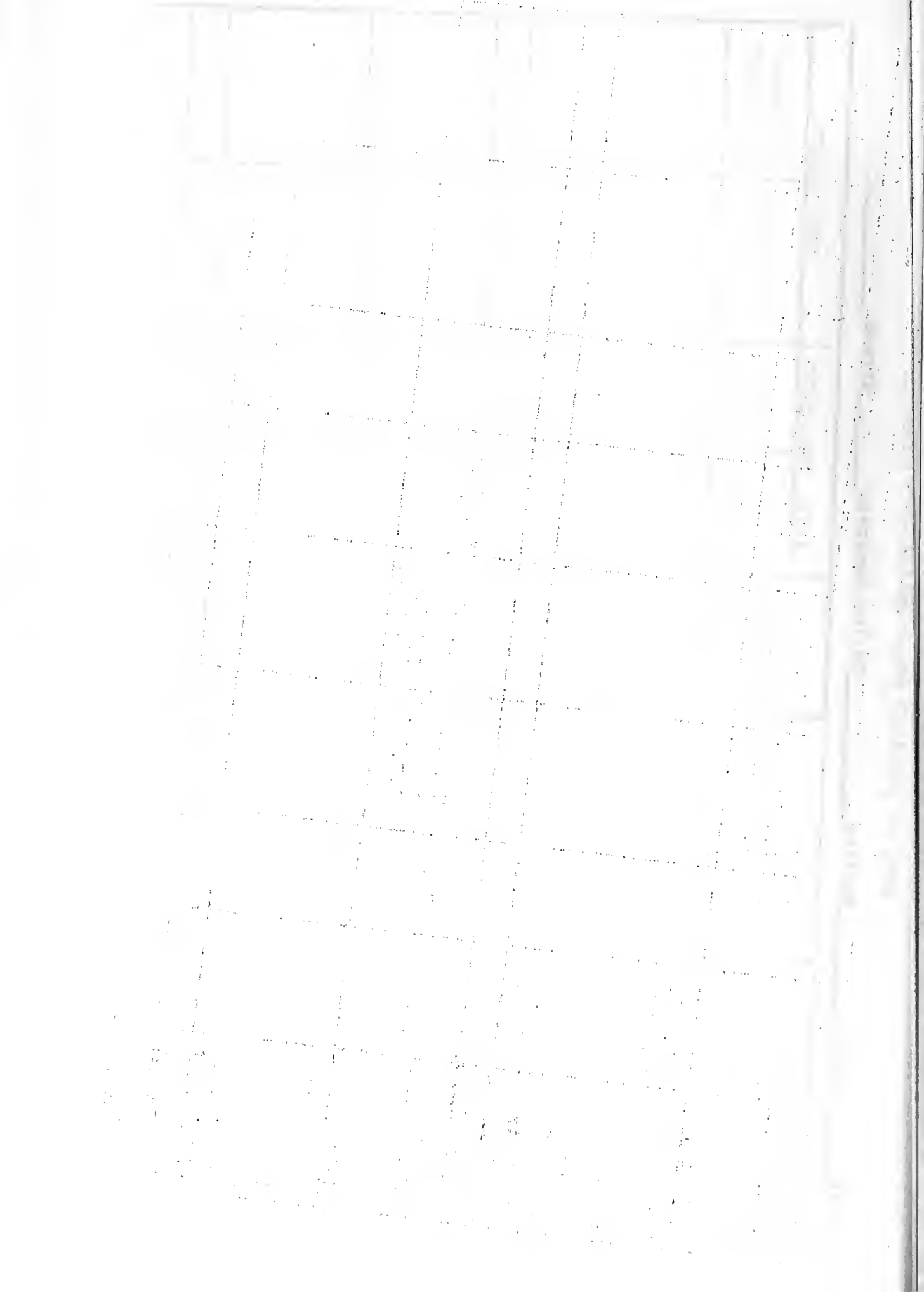




# COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 20' Load 500 ppf Section 12.5"x6" Cu Yds Concrete 0.39 Strand 1-1 1/2"

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased steel Forms	S.F.C.S. per form	\$2.25	117	2085	\$939.00	\$4695.00	\$ 9.39	\$ 93.90
Strand							7,845.00	78,450.00
Bearing Assembly							268.00	2,620.00
Ready Mix Concrete	Cu. Yd.	\$11.15	39	390			435.00	4,350.00
Total-Mat'l.							\$8,557.39	\$85,513.90
ITEM								
Labor					No. Units per Beam			
Carpenters	Hour	\$3.09	3.5	.417			\$ 451.00	\$ 4,510.00
Common Labor	Hour	\$1.90	2	.417			158.20	1,582.00
Structural Iron Worker	Hour	\$3.25			1/2		162.50	1,625.00
Total-Labor							\$ 771.70	\$ 7,717.00
TOTAL							\$9,329.09	\$93,230.90



# COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

Length 30' Load 100 ppf Section 7.5"x13.5" Cu Yds Concrete .781 Lbs Reinforced Steel 170.5

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST		COST ALLOWED	
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	\$ .296	86.25	172.5	\$25.53	\$51.06	\$12.76	\$ 51.06
Reinforcing Bars	Pound	\$ .0879	170.5	1705	15.00	150.00	15.00	150.00
Ready Mix Concrete	Cu. Yd.	\$11.15	.781	7.81	8.70	87.00	8.70	87.00
Total-Mat'l.							\$36.46	\$288.06
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies			
Labor					1 Form	2 Forms		
Carpenter	Hour	9	\$3.09	.8625	1	10	\$23.99	\$239.90
Common Labor	Hour	6.5	\$1.90	.8625	1	10	10.64	106.40
Total-Labor							\$34.63	\$346.30
TOTAL							\$71.09	\$634.36



# COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

43

Length 30' Load 100 ppf Section 9.5"x5" Cu Yds Concrete 0.37 Strand 1-1"

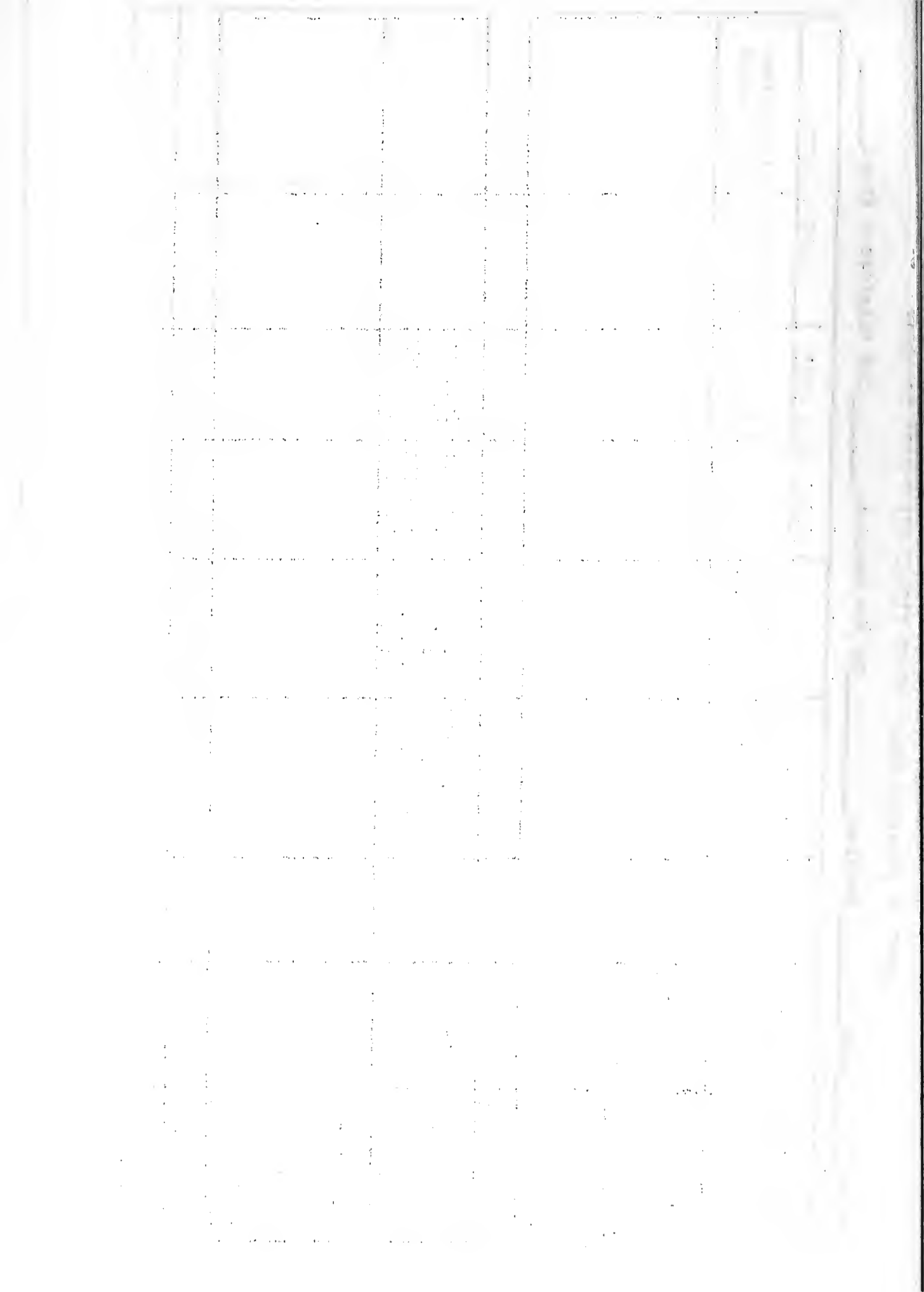
ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST			COST ALLOWED	
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams	
Material									
Plywood Forms	S.F.C.S.	\$ .296	60.0	120.0	\$17.75	\$35.50	\$ 8.88	\$ 35.50	
Strand							46.75	467.50	
Bearing Assembly							2.49	24.90	
Ready Mix Concrete	Cu. Yd.	\$11.15	0.37	3.7			4.13	41.30	
Total-Mat'l.							\$62.25	\$569.20	
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies				
Labor					1 Form	2 Forms			
Carpenter	Hour	9	\$3.09	.60	1	10	\$16.68	\$166.80	
Common Labor	Hour	6.5	\$1.90	.60	1	10	7.41	74.10	
Total-Labor							\$24.09	\$240.90	
TOTAL							\$86.34	\$810.10	



COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

Length 30' Load 100 ppf Section 7.5"x13.5" Cu Yds Concrete .781 Lbs Reinforced Steel 170.5

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	675	3,375	\$1519.00	\$7595.00	\$ 15.19	\$ 151.90
Reinforcing Bars	Pound	\$ .0844	17,050	170,500	-	-	1,439.00	14,390.00
Ready Mix Concrete	Cu. Yd.	\$11.15	78.1	781	-	-	870.00	8,700.00
Total-Mat'l.							\$2,324.19	\$23,241.90
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams		
Labor								
Carpenters	Hour	\$3.09	3.5	.675	-	-	\$ 729.00	\$ 7,290.00
Common Labor	Hour	\$1.90	2	.675	-	-	257.00	2,570.00
Structural Iron Worker	Cwt. of steel	\$1.95	-	-	170.5	1705	332.50	3,325.00
Total-Labor							\$1,318.50	\$13,185.00
TOTAL							\$3,642.69	\$36,426.90





## COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 30' Load 100 ppf Section 9.5"x5" Cu Yds Concrete 0.37 Strand 1-1"

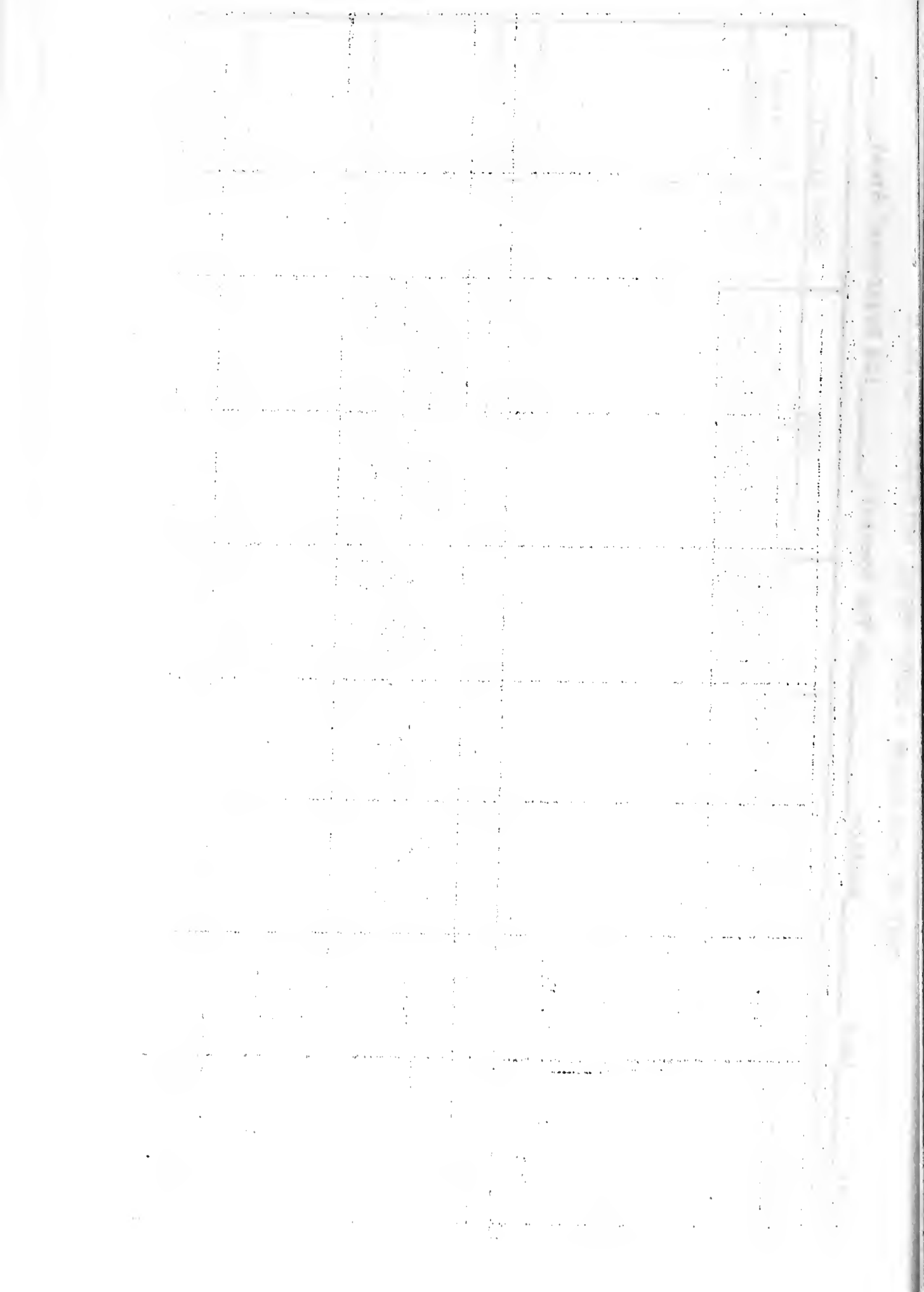
ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased steel Forms	S.F.C.S. per form	\$2.25	476	2380	\$1070.00	\$5350.00	\$ 10.70	\$ 107.00
Strand								
Bearing Assembly							4,675.00	46,750.00
Ready Mix Concrete	Cu. Yd.	\$11.15	37.0	370.0			249.00	2,460.00
							413.00	4,130.00
Total-Mat'l.							\$5,347.70	\$53,447.00
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	No. Units per Beam			
Labor								
Carpenters	Hour	\$3.09	3.5	.476			\$ 514.50	\$ 5,145.00
Common Labor	Hour	\$1.90	2	.476			181.40	1,814.00
Structural Iron Worker	Hour	\$3.25			1/2		162.50	1,625.00
Total-Labor							\$ 858.40	\$ 8,584.00
TOTAL							\$6,206.10	\$62,031.00



Length 30' Load 200 ppf Section 7.5"x16" Cu Yds Concrete .925 Lbs Reinforced Steel 217.5

Total-Mat'l.

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST		COST ALLOWED	
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	\$ .296	98.7	197.4	\$29.20	\$58.40	\$14.60	\$ 58.40
Reinforcing Bars	Pound	\$ .0879	217.5	2175	-	-	19.13	191.30
Ready Mix Concrete	Cu. Yd.	\$11.15	.925	9.25	-	-	10.31	103.10
Total-Mat'l.							\$44.04	\$352.80
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies			
Labor					1 Form	2 Forms		
Carpenter	Hour	9	\$3.09	.9875	1	10	\$27.42	\$274.20
Common Labor	Hour	6.5	\$1.90	.9875	1	10	12.19	121.90
Total-Labor							\$39.61	\$396.10
TOTAL							\$83.65	\$748.90



## COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

Length 30' Load 200 ppf Section 13" x 5.5" Cu Yds Concrete 0.55 Strand 1-1<sup>1</sup>/<sub>16</sub>"

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ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST			COST ALLOWED
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	
Material								
Plywood Forms	S.F.C.S.	\$ .296	78.75	157.50	\$23.30	\$46.60	\$11.65	\$ 46.60
Strand							\$0.50	\$05.00
Bearing Assembly							2.63	26.30
Ready Mix Concrete	Cu. Yd.	\$11.15	0.55	5.5			6.13	61.30
Total-Mat'l.							\$100.91	\$ 939.20
ITEM								
Labor								
	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies			
					1 Form	2 Forms		
Carpenter	Hour	9	\$3.09	.7875	1	10	\$ 21.90	\$ 219.00
Common Labor	Hour	6.5	\$1.90	.7875	1	10	9.71	97.10
Total-Labor							\$ 31.61	\$ 316.10
TOTAL							\$132.52	\$1,255.30

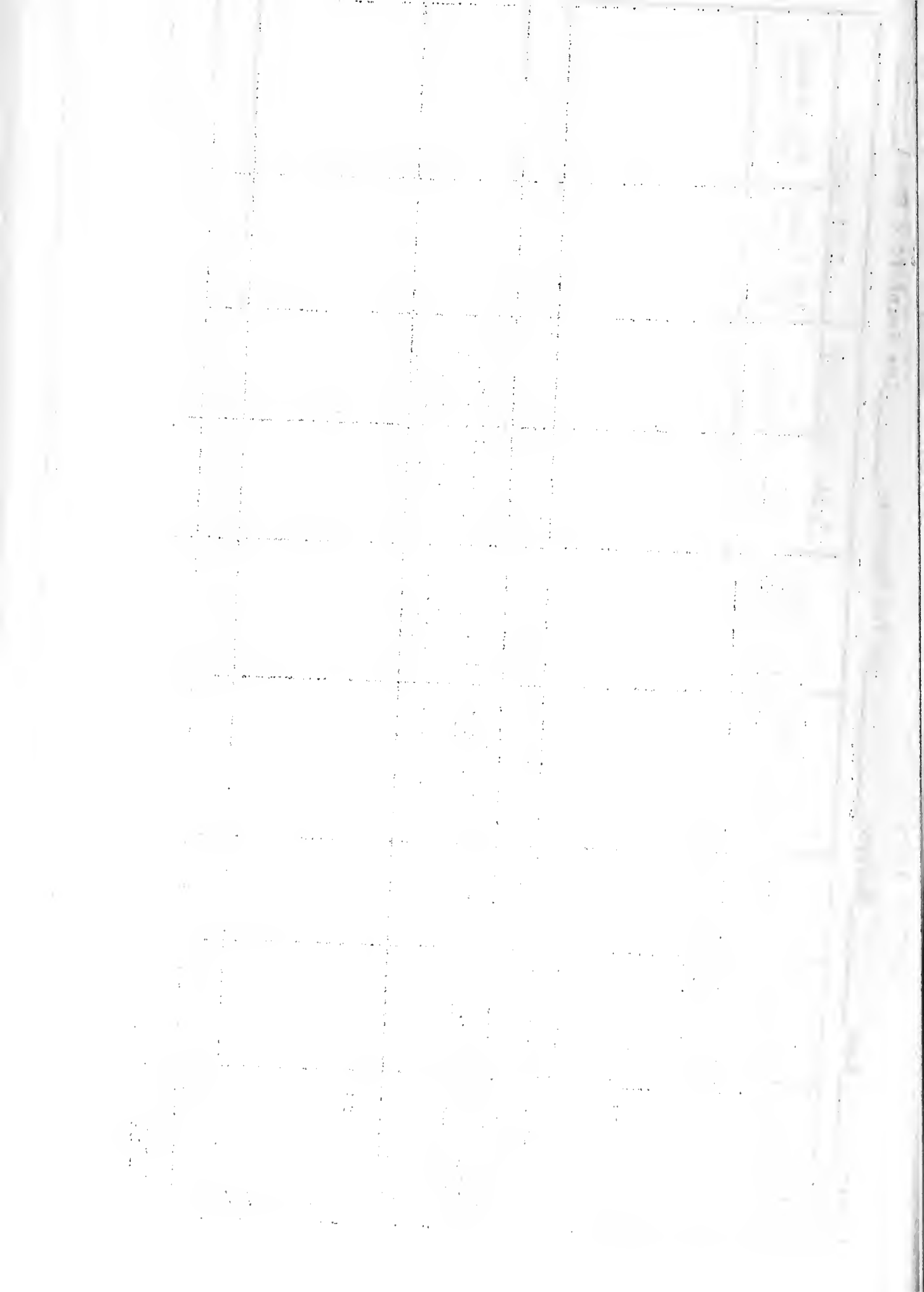


# COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

48

Length 30' Load 200 ppf Section 7.5"x16" Cu Yds Concrete .925 Lbs Reinforced Steel 217.5

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	800	4,000	\$1800.00	\$9000.00	\$ 18.00	\$ 180.00
Reinforcing Bars	Pound	\$ .0844	21,750	217,500	-	-	1,837.00	18,370.00
Ready Mix Concrete	Cu. Yd.	\$11.15	92.5	925	-	-	1,031.00	10,310.00
Total-Mat'l.							\$2,886.00	\$28,860.00
ITEM								
Labor								
Carpenters	Hour	\$3.09	3.5	.8	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams	\$ 864.00	\$ 8,640.00
Common Labor	Hour	\$1.90	2	.8	-	-	304.00	3,040.00
Structural Iron Worker	Cwt. of Steel	\$1.95	-	-	217.5	2175.0	424.00	4,240.00
Total-Labor							\$1,592.00	\$15,920.00
TOTAL							\$4,478.00	\$44,780.00





# COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 30' Load 200 ppf Section 13"x5.5" Cu Yds Concrete 0.55 Strand 1-1 1/16"

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	650	3250	\$1462.50	\$7312.50	\$ 14.62	\$ 146.20
Strand							\$ 8,050.00	\$ 80,500.00
Bearing Assembly							263.00	2,600.00
Ready Mix Concrete	Cu. Yd.	\$11.15	55	550			613.00	6,130.00
Total-Mat'l.							\$ 8,940.62	\$ 89,378.20
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	No. Units per Beam			
Labor								
Carpenters	Hour	\$3.09	3.5	.65			\$ 702.00	\$ 7,020.00
Common Labor	Hour	\$1.90	2	.65			247.00	2,470.00
Structural Iron Worker	Hour	\$3.25			1/2		162.50	1,625.00
Total-Labor							\$ 1,111.50	\$ 11,115.00
TOTAL							\$10,052.12	\$100,493.20



Length 70' Load 300 pnf Section " 14" Cu Yds Concrete 1.11 Lbs Reinforced Steel 276.0

Total-Mat'l.

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST		COST ALLOWED	
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	\$1.296	110	220	\$32.55	\$65.10	\$16.28	\$65.10
Reinforcing Bars	Pound	\$0.0879	276	2760	-	-	24.30	243.00
Ready Mix Concrete	Cu. Yd.	\$11.15	1.11	11.10	-	-	12.38	123.80
Total-Mat'l.							\$52.96	\$431.90
ITEM								
Labor								
	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies			
					1 Form	2 Forms		
Carpenter	Hour	9	\$3.09	1.1	1	10	\$30.59	\$305.90
Common Labor	Hour	6.5	\$1.90	1.1	1	10	13.59	135.90
Total-Labor							\$44.18	\$441.80
TOTAL							\$97.14	\$873.70

11

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1. The first step is to identify the key components of the system. This involves understanding the hardware, software, and data involved in the process.

# COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

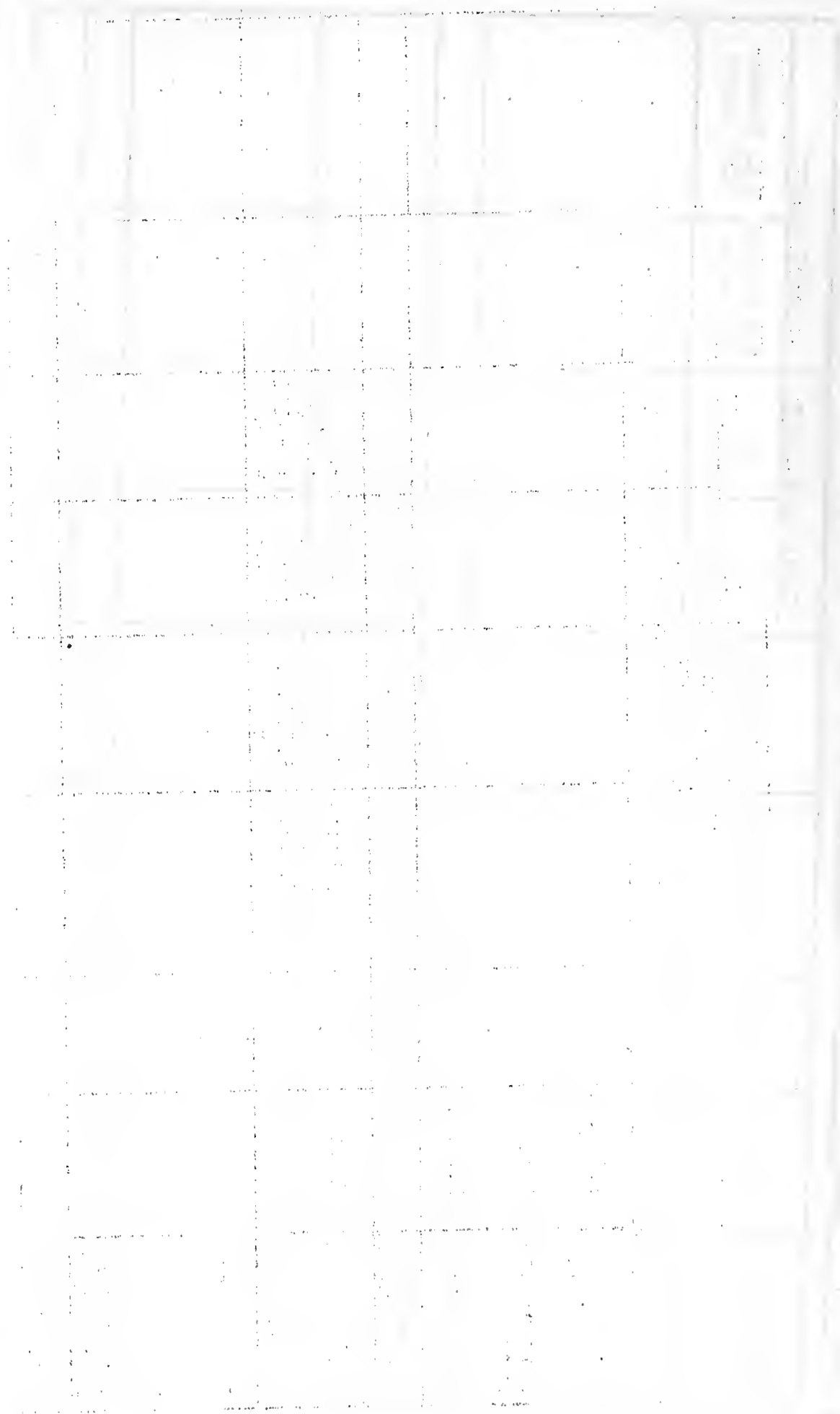
Length 30' Load 300 ppf Section 15" x 6" Cu Yds Concrete 0.70 Strand 1-1<sup>3</sup>/<sub>16</sub>"

ITEM		Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST			COST ALLOWED
						(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	
Material									
Plywood Forms	S.F.C.S.	\$ .296		90.0	180.0	\$26.60	\$53.20	\$ 13.30	\$ 53.20
Strand								90.45	904.50
Bearing Assembly								2.68	26.80
Ready Mix Concrete	Cu. Yd.	\$11.15	0.70		7.0			7.81	78.10
Total-Mat'l.								\$114.24	\$1,062.60
ITEM		Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies			
						1 Form	2 Forms		
Labor									
Carpenter	Hour	9	\$3.09	.90		1	10	\$ 25.05	\$ 250.50
Common Labor	Hour	6.5	\$1.90	.90		1	10	11.12	111.20
Total-Labor								\$ 36.17	\$ 361.70
TOTAL								\$150.41	\$1,424.30



Length 30' Load 300 pnf Section 8" x 18" Cu Yds Concrete 1.11 Lbs Reinforced Steel 276.0

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	900	4500	\$2025.00	\$10125.00	\$ 20.25	\$ 202.50
Reinforcing Bars	Pound	\$ .0844	27,600	276,000	-	-	2,230.00	22,300.00
Ready Mix Concrete	Cu. Yd.	\$11.15	111	1,110	-	-	1,238.00	12,380.00
Total-Mat'l.							\$3,483.25	\$34,882.50
ITEM								
Labor								
Carpenters	Hour	\$3.09	3.5	.9	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams	\$ 972.00	\$ 9,720.00
Common Labor	Hour	\$1.90	2	.9	-	-	342.00	3,420.00
Structural Iron Worker	Cwt. of Steel	\$1.95	-	-	276	2760	538.00	5,380.00
Total-Labor							\$1,852.00	\$18,520.00
TOTAL							\$5,340.25	\$53,402.50





# COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 30' Load 300 ppi Section 15"x6" Cu Yds Concrete 0.70 Strand 1-1 1/2" 16

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	750	3750	\$1690.00	\$8450.00	\$ 16.90	\$ 169.00
Strand								
Bearing Assembly							9,045.00	90,450.00
Ready Mix Concrete	Cu. Yd.	\$11.15	70	700			268.00	2,650.00
							781.00	7,810.00
Total-Mat'l.							\$10,110.90	\$101,079.00
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	No. Units per Beam			
Labor								
Carpenters	Hour	\$3.09	3.5	.75			\$ 810.00	\$ 8,100.00
Common Labor	Hour	\$1.90	2	.75			285.00	2,850.00
Structural Iron Worker	Hour	\$3.25			1/2		162.50	1,625.00
Total-Labor							\$ 1,257.50	\$ 12,575.00
TOTAL							\$11,368.40	\$113,654.00



Length 30' Load 400 pcf Section 9"x19.5" Cu Yds Concrete 1.36 Lbs Reinforced Steel 744.4

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST		COST ALLOTTED	
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	\$1.296	120	240	\$35.55	\$71.10	\$17.78	\$71.10
Reinforcing Bars	Pound	1.0879	344.4	344.4	-	-	30.30	303.00
Ready Mix Concrete	Cu. Yd.	\$11.15	1.36	13.6	-	-	15.17	151.70
Total-Mat'l.							\$63.25	\$525.80
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies			
Labor					1 Form	2 Forms		
Carpenter	Hour	9	\$3.09	1.20	1	10	\$33.35	\$333.50
Common Labor	Hour	6.5	\$1.90	1.20	1	10	14.83	148.30
Total-Labor							\$48.18	\$481.80
TOTAL							\$111.43	\$1007.60

1990

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# COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

Length 30' Load 400 ppf Section 16.5"x6.5" Cu Yds Concrete 0.83 Strand 1-1<sup>1</sup>/<sub>2</sub>"  
16

55

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST		COST ALLOWED	
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	\$ .296	33.75	197.50	\$29.20	\$58.40	\$ 14.60	\$ 58.40
Strand							108.15	1,081.50
Bearing Assembly							2.79	27.90
Ready Mix Concrete	Cu. Yd.	\$11.15	0.83	8.30			9.26	92.60
Total-Mat'l.							\$134.80	\$1,260.40
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies			
Labor					1 Form	2 Forms		
Carpenter	Hour	9	\$3.09	.9875	1	10	\$ 27.45	\$ 274.50
Common Labor	Hour	6.5	\$1.90	.9875	1	10	12.19	121.90
Total-Labor							\$ 39.64	\$ 396.40
TOTAL							\$174.44	\$1,656.80

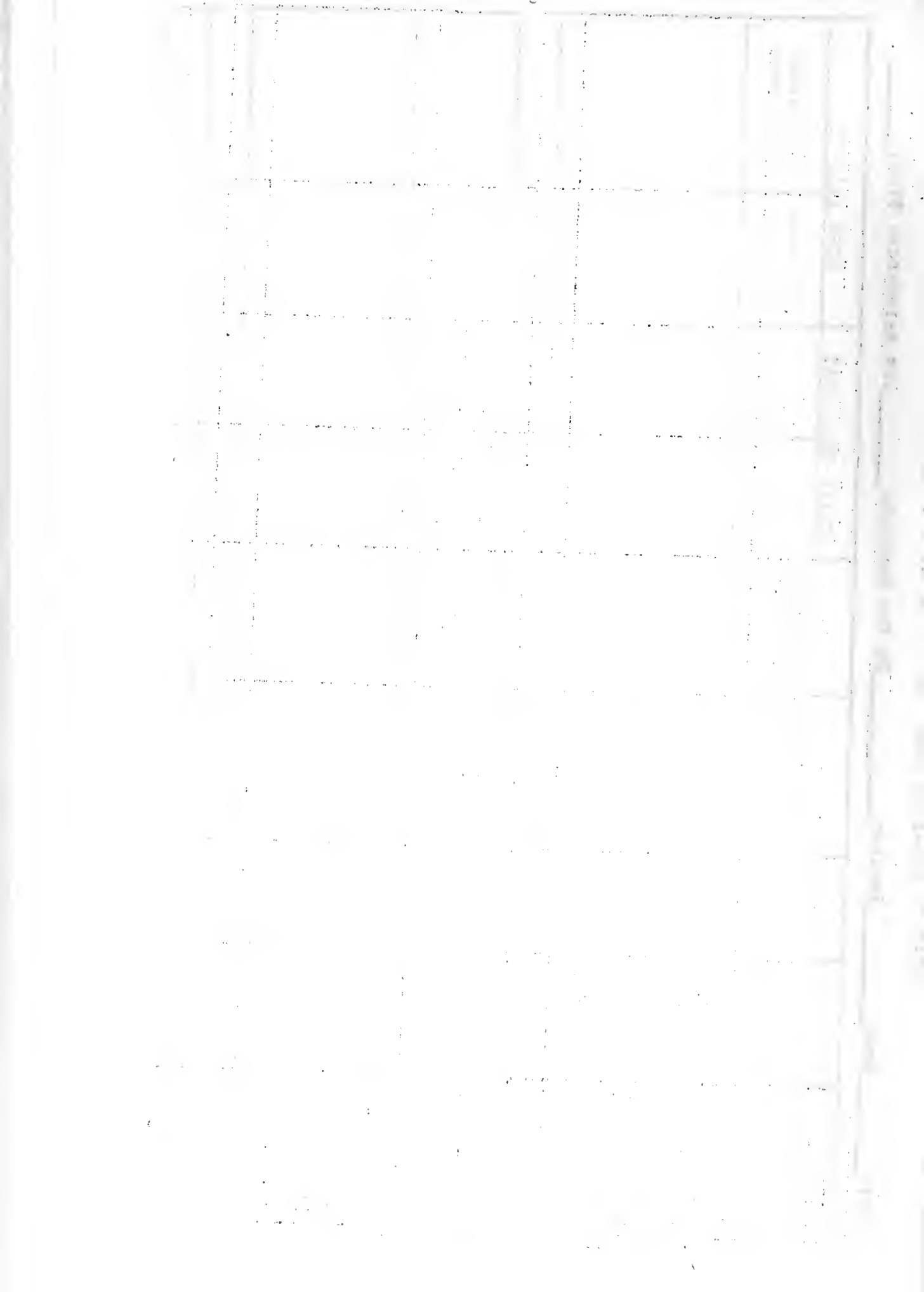


## COST OF 100-1000 BEAM- CONVENTIONAL REINFORCED CONCRETE

56

Length 30' Load 400 pps Section 9"x19.5" Cu Yds Concrete 1.36 Lbs Reinforced Steel 3444

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	975	4,875	\$2193.00	\$10965.00	\$21.93	\$219.30
Reinforcing Bars	Pound	\$1.0844	34,440	344,400	-	-	2,908.00	29,080.00
Ready Mix Concrete	Cu. Yd.	\$11.15	136	1,360	-	-	1,517.00	15,170.00
Total-Mat'l.							\$4,446.93	\$44,469.30
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams		
Labor								
Carpenters	Hour	\$3.09	3.5	.975	-	-	\$1,054.00	\$10,540.00
Common Labor	Hour	\$1.90	2	.975	-	-	370.00	3,700.00
Structural Iron Worker	Cwt. of steel	\$1.95	-	-	34.4	3,444	672.00	6,720.00
Total-Labor							\$2,096.00	\$20,960.00
TOTAL							\$6,542.93	\$65,429.30





# COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 30' Load 400 ppf Section 16.5"x6.5" Cu Yds Concrete 0.53 Strand 1-1 1/2"

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	825	4125	\$1855.00	\$9275.00	\$ 18.55	\$ 185.50
Strand							10,815.00	108,150.00
Bearing Assembly							279.00	2,760.00
Ready Mix Concrete	Cu. Yd.	\$11.15	83	830			926.00	9,260.00
Total-Mat'l.							\$12,038.55	\$120,355.50
ITEM								
Labor								
Carpenters	Hour	\$3.09	3.5	.825	No. Units per Beam		\$ 891.00	\$ 8,910.00
Common Labor	Hour	\$1.90	2	.825			313.50	3,135.00
Structural Iron Worker	Hour	\$3.25			1/2		162.50	1,625.00
Total-Labor							\$ 1,367.00	\$ 13,670.00
TOTAL							\$13,405.55	\$134,025.50



# COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

Length 30' Load 500 ppf Section 10"x20.5" Cu Yds Concrete 1.58 Lbs Reinforced Steel 344.4

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST		COST ALLOWED	
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	\$ .296	127.5	255	\$37.75	\$75.50	\$ 18.86	\$ 75.50
Reinforcing Bars	Pound	\$ .0879	344.4	3444	-	-	30.30	303.00
Ready Mix Concrete	Cu. Yd.	\$11.15	1.58	15.8	-	-	17.61	176.10
Total-Mat'l.							\$ 66.77	\$ 554.60
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies			
Labor					1 Form	2 Forms		
Carpenter	Hour	9	\$3.09	1.275	1	10	\$ 35.40	\$ 354.00
Common Labor	Hour	6.5	\$1.90	1.275	1	10	15.75	157.50
Total-Labor							\$ 51.15	\$ 511.50
TOTAL							\$117.92	\$1,066.10

1. The first part of the document is a list of names and titles, including "The Hon. Mr. Justice" and "The Hon. Mr. Justice".

## COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

 Length 30' Load 500 lbs Section 17.5"x7" Cu Yds Concrete 0.95 Strand 1-1<sup>3</sup>/<sub>8</sub>"

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST		
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam
Material							
Flywood Forms	S.F.C.S.	\$ .296	105.05	210.10	\$31.10	\$62.20	\$ 15.55
Strand							\$ 62.20
Bearing Assembly							1,150.00
Ready Mix Concrete	Cu. Yd.	\$11.15	0.95	9.50			2.91
							105.90
Total-Mat'l.							\$144.05
ITEM							
Labor	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies		
					1 Form	2 Forms	
Carpenter	Hour	9	\$3.20	1.05	1	10	\$ 29.20
Common Labor	Hour	6.5	\$1.90	1.05	1	10	12.97
							\$ 42.17
Total-Labor							\$186.22
TOTAL							\$1,768.90



COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

Length 30' Load 500 ppf Section 10"x20.5" Cu Yds Concrete 1.58 Lbs Reinforced Steel 344.4

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	1,050	5,250	\$2361.00	\$11805.00	\$ 23.61	\$ 236.10
Reinforcing Bars	Pound	\$ .0844	34,440	344,400	-	-	2,908.00	29,080.00
Ready Mix Concrete	Cu. Yd.	\$11.15	158	1,580	-	-	1,760.00	17,600.00
Total-Mat'l.							\$4,691.61	\$46,916.10
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams		
Labor								
Carpenters	Hour	\$7.09	3.5	1.05	-	-	\$1,135.00	\$11,350.00
Common Labor	Hour	\$1.90	2	1.05	-	-	399.00	3,990.00
Structural Iron Worker	Cwt. of steel	\$1.95	-	-	344.4	3,444	672.00	6,720.00
Total-Labor							\$2,206.00	\$22,060.00
TOTAL							\$6,897.61	\$68,976.10





## COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 30' Load 500 ppf Section 17.5"x7" Cu Yds Concrete 0.95 Strand 1-13"

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	875	4,375	\$1970.00	\$9850.00	\$ 19.70	\$ 197.00
Strand							11,500.00	115,000.00
Bearing Assembly							291.00	2,880.00
Ready Mix Concrete	Cu. Yd.	\$11.15	95	950			1,059.00	10,590.00
Total-Mat'l.							\$12,869.70	\$128,667.00
ITEM								
Labor	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	No. Units per Beam			
Carpenters	Hour	\$3.09	3.5	.875			\$ 948.00	\$ 9,480.00
Common Labor	Hour	\$1.90	2	.875			333.50	3,335.00
Structural Iron Worker	Hour	\$3.25			1/2		162.50	1,625.00
Total-Labor							\$ 1,454.00	\$ 14,540.00
TOTAL							\$14,323.70	\$143,207.00



Length 40' Load 100 ppf Section 8"x18.5" Cu Yds Concrete 1.52 Lbs Reinforced Steel 364

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST		COST ALLOWED	
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	\$ .296	150	300	\$44.35	\$88.70	\$ 22.18	\$ 88.70
Reinforcing Bars	Pound	\$ .0879	364	3640	-	-	32.00	320.00
Ready Mix Concrete	Cu. Yd.	\$ 11.15	1.52	15.2	-	-	16.95	169.50
Total-Mat'l.							\$ 71.13	\$ 578.20
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies			
					1 Form	2 Forms		
Labor								
Carpenter	Hour	9	\$3.09	1.502	1	10	\$ 41.75	\$ 417.50
Common Labor	Hour	6.5	\$1.90	1.502	1	10	18.58	185.80
Total-Labor							\$ 60.33	\$ 603.30
TOTAL							\$131.46	\$1,181.50



Length 40' Load 100 ppf Section 11.5"x6.5" Cu Yds Concrete 0.77 Strand 1-1 1/4"

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST			COST ALLOWED		
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams
Material										
Flywood Forms	S.F.C.S.	\$1.296	98.3	196.6	\$29.10	\$58.20	\$14.55	\$58.20		
Strand							108.90	1,089.00		
Bearing Assembly							2.79	27.90		
Ready Mix Concrete	Cu. Yd.	\$11.15	0.77	7.7			8.59	85.90		
Total-Mat'l.							\$134.83	\$1,261.00		
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies					
Labor					1 Form	2 Forms				
Carpenter	Hour	9	\$3.09	.983	1	10	\$27.35	\$273.50		
Common Labor	Hour	6.5	\$1.90	.983	1	10	12.13	121.30		
Total-Labor							\$39.48	\$394.80		
TOTAL							\$174.31	\$1,655.80		



## COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

Length 40' Load 100 ppf Section 8"x18.5" Cu Yds Concrete 1.52 Lbs Reinforced Steel 364

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	1,232	6,160	\$2773.00	\$13865.00	\$ 27.73	\$ 277.30
Reinforcing Bars	Pound	\$ .0844	36,400	364,000	-	-	3,072.00	30,720.00
Ready Mix Concrete	Cu. Yd.	\$11.15	152	1,520	-	-	1,695.00	16,950.00
Total-Mat'l.							\$4,794.73	\$47,947.30
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams		
Labor								
Carpenters	Hour	\$3.09	3.5	1.232	-	-	\$1,330.00	\$13,300.00
Common Labor	Hour	\$1.90	2	1.232	-	-	465.00	4,650.00
Structural Iron Worker	Cwt. of Steel	\$1.95	-	-	364	3,640	710.00	7,100.00
Total-Labor							\$2,505.00	\$25,050.00
TOTAL							\$7,302.73	\$73,027.30



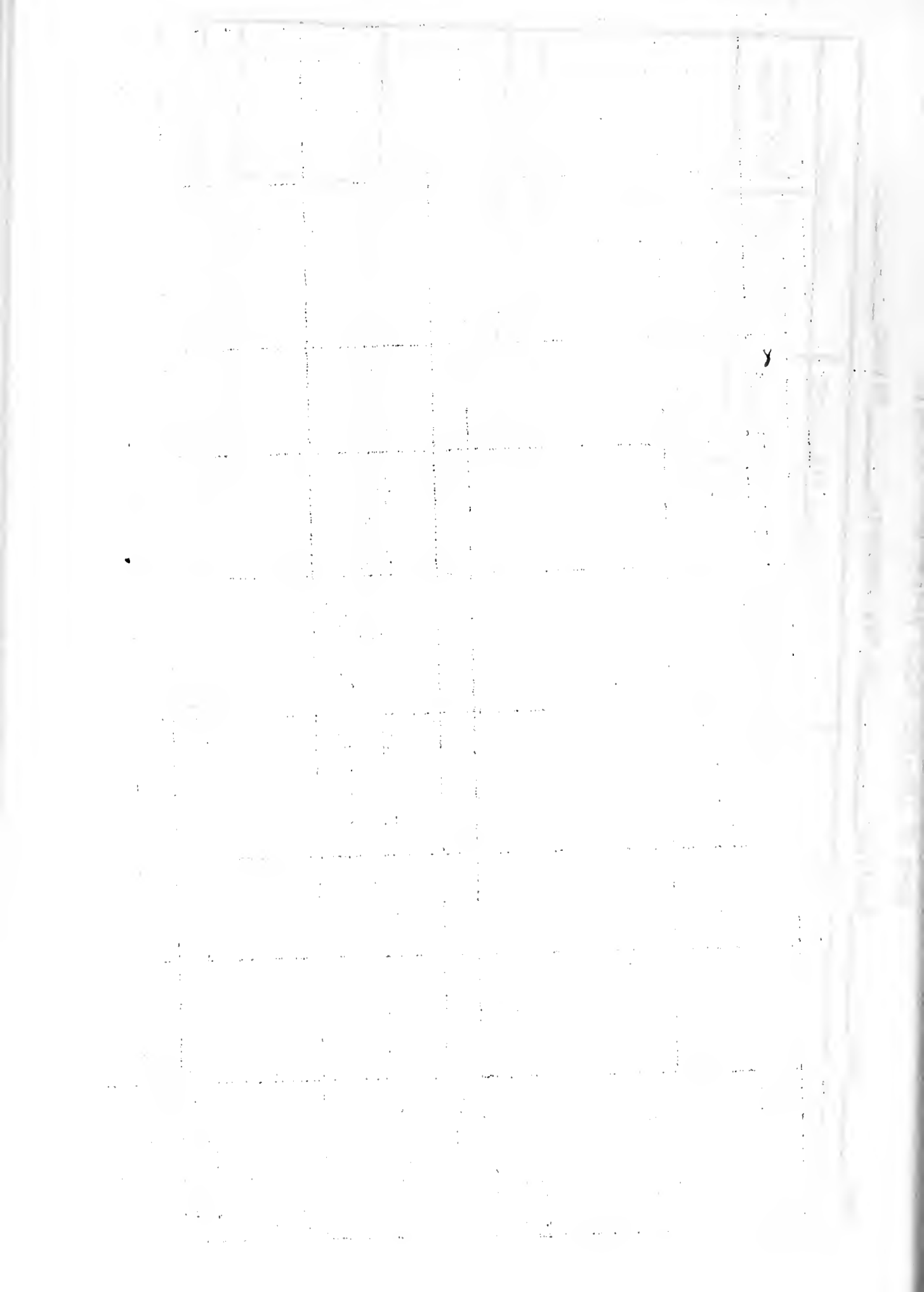


COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 40' Load 100 ppf Section 11.5"x6.5" Cu Yds Concrete 0.77 Strand 1-1 $\frac{1}{4}$ "

65

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	767	3,835	\$1725.00	\$8625.00	\$ 17.25	\$ 172.50
Strand							10,890.00	108,900.00
Bearing Assembly							279.00	2,760.00
Ready Mix Concrete	Cu. Yd.	\$11.15	77	770			\$59.00	\$,590.00
Total-Mat'l.							\$12,045.25	\$120,422.50
ITEM								
Labor								
Carpenters	Hour	\$3.09	3.5	.767	No. Units per Beam		\$ 828.00	\$ 8,280.00
Common Labor	Hour	\$1.90	2	.767			291.50	2,915.00
Structural Iron "Orker"	Hour	\$3.25			1/2		162.50	1,625.00
Total-Labor							\$ 1,282.00	\$ 12,820.00
TOTAL							\$13,327.25	\$133,242.00



COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

Length 40' Load 200 psf Section 10" x 21" Cu Yds Concrete 2.16 Lbs Reinforced Steel 420

66

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST		COST ALLOTTED	
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	\$1.296	173.2	346.4	\$51.30	\$102.60	\$25.65	\$102.60
Reinforcing Bars	Pound	1.0879	420	4,200	-	-	36.95	369.50
Ready Mix Concrete	Cu. Yd.	111.15	2.16	21.6	-	-	24.10	241.00
Total-Mat'l.							\$86.70	\$713.10
ITEM								
Labor	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies			
					1 Form	2 Forms		
Carpenter	Hour	9	\$3.09	1.735	1	10	\$48.20	\$482.00
Common Labor	Hour	6.5	\$1.90	1.735	1	10	21.40	214.00
Total-Labor							\$69.60	\$696.00
TOTAL							\$156.30	\$1,409.10



COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

Length 40' Load 200 ppf Section 14.5"x8" Cu Yds Concrete 1.20 Strand 1-18<sup>3</sup>

67

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST		
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam
Material							
Plywood Forms	S.F.C.S.	\$ .296	123.4	246.8	\$36.60	\$73.20	\$ 18.30
Strand							
Bearing Assembly							
Ready Mix Concrete	Cu. Yd.	\$11.15	1.20	12.0			
Total-Mat'l.							\$163.67
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies		
Labor					1 Form	2 Forms	
Carpenter	Hour	9	\$3.09	1.234	1	10	\$ 34.30
Common Labor	Hour	6.5	\$1.90	1.234	1	10	15.23
Total-Labor							\$ 49.53
TOTAL							\$213.20
							\$2,022.20

(2 Forms)  
10 Beams

(1 Form)  
1 Beam

(2 Forms)  
10 Beams

(1 Form)  
1 Beam

No. Units  
(2 Forms)  
10 Beams

No. Units  
1 Beam

Unit Cost

Unit

ITEM

Labor

Carpenter

Common Labor

Total-Labor

TOTAL



# COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

Length 40' Load 200 ppf Section 10" x 21" Cu Yds Concrete 2.16 Lbs Reinforced Steel 420

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	1,400	7,000	\$3150.00	\$15750.00	\$ 31.50	\$ 315.00
Reinforcing Bars	Pound	\$.0844	42,000	420,000	-	-	3,545.00	35,450.00
Ready Mix Concrete	Cu. Yd.	\$11.15	216	2,160	-	-	2,408.00	24,080.00
Total-Mat'l.							\$5,984.50	\$59,845.00
ITEM								
Labor								
Carpenters	Hour	\$3.09	3.5	1.4	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams	\$1,512.00	\$15,120.00
Common Labor	Hour	\$1.90	2	1.4	-	-	532.50	5,325.00
Structural Iron Worker	Cwt. of Steel	\$1.95	-	-	420.0	4,200.0	\$19.00	\$,190.00
Total-Labor							\$2,863.50	\$28,635.00
TOTAL							\$8,848.00	\$88,480.00





**COST OF 100-1000 BEAMS PRESTRESSED CONCRETE**

Length 40' Load 200 ppf Section 14.5"x8" Cu Yds Concrete 1.20 Strand 1-12"

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	967	4,835	\$2175.00	\$10875.	\$ 21.75	\$ 217.50
Strand							12,880.00	128,800.00
Bearing Assembly							318.00	3,150.00
Ready Mix Concrete	Cu. Yd.	\$11.15	120	1,200			1,339.00	13,390.00
Total-Mat'l.							\$14,558.75	\$145,557.50
ITEM								
Labor								
Carpenters	Hour	\$3.09	3.5	.967	No. Units per Beam		\$ 1,045.00	\$ 10,450.00
Common Labor	Hour	\$1.90	2	.967			367.50	3,675.00
Structural Iron Worker	Hour	\$3.25			1/2		162.50	1,625.00
Total-Labor							\$ 1,575.00	\$ 15,750.00
TOTAL							\$16,133.75	\$161,307.50



# COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

70

Length 40' Load 300 pps Section 10"x23.5" Cu Yds Concrete 2.42 Lbs Reinforced Steel 546

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST		COST ALLOWED	
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	\$ .296	190	380	\$56.25	\$112.50	\$ 28.13	\$ 112.50
Reinforcing Bars	Pound	\$ .0879	546	5,460	-	-	48.00	480.00
Ready Mix Concrete	Cu. Yd.	\$11.15	2.42	24.2	-	-	27.00	270.00
Total-Mat'l.							\$103.13	\$ 862.50
ITEM								
Labor	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies			
					1 Form	2 Forms		
Carpenter	Hour	9	\$3.09	1.898	1	10	\$ 52.75	\$ 527.50
Common Labor	Hour	6.5	\$1.90	1.898	1	10	23.40	234.00
Total-Labor							\$ 76.15	\$ 761.50
TOTAL							\$179.28	\$1,624.00

12-10-1964

# COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

Length 40' Load 300 ppf Section 16.5"x9" Cu Yds Concrete 1.53 Strand 1-1 9/16"

71

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST			COST ALLOWED		
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams
Material										
Plywood Forms	S.F.C.S.	\$ .296	140.0	280.0	\$41.40	\$82.80	\$ 20.70	\$ 82.80		
Strand										
Bearing Assembly										
Ready Mix Concrete	Cu. Yd.	\$11.15	1.53	15.3			163.20	1,632.00	3.49	34.90
Total-Mat'l.							17.09	170.90		
							\$204.48	\$ 1,920.60		
Labor										
	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	Mo. Assemblies & Disassemblies					
					1 Form	2 Forms				
Carpenter	Hour	9	\$3.09	1.40	1	10	\$ 38.90	\$ 389.00		
Common Labor	Hour	6.5	\$1.90	1.40	1	10	17.30	173.00		
Total-Labor							\$ 56.20	\$ 562.00		
TOTAL							\$260.68	\$2,482.60		



COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

Length 40' Load 300 ppf Section 10"x23.5" Cu Yds Concrete 2.42 Lbs Reinforced Steel 546

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	1,568	7,840	\$3525.00	\$17625.00	\$ 35.25	\$ 352.50
Reinforcing Bars	Pound	\$ .0844	54,600	546,000	-	-	4,610.00	46,100.00
Ready Mix Concrete	Cu. Yd.	\$11.15	242	2,420	-	-	2,699.00	26,990.00
Total-Mat'l.							\$ 7,344.25	\$ 73,442.50
ITEM								
Labor								
Carpenters	Hour	\$3.09	3.5	1.568	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams	\$ 1,693.00	\$ 16,930.00
Common Labor	Hour	\$1.90	2	1.568	-	-	595.00	5,950.00
Structural Iron Worker	Cwt. of Steel	\$1.95	-	-	546	5,460	1,064.00	10,640.00
Total-Labor							\$ 3,352.00	\$ 33,520.00
TOTAL							\$10,696.25	\$106,962.50



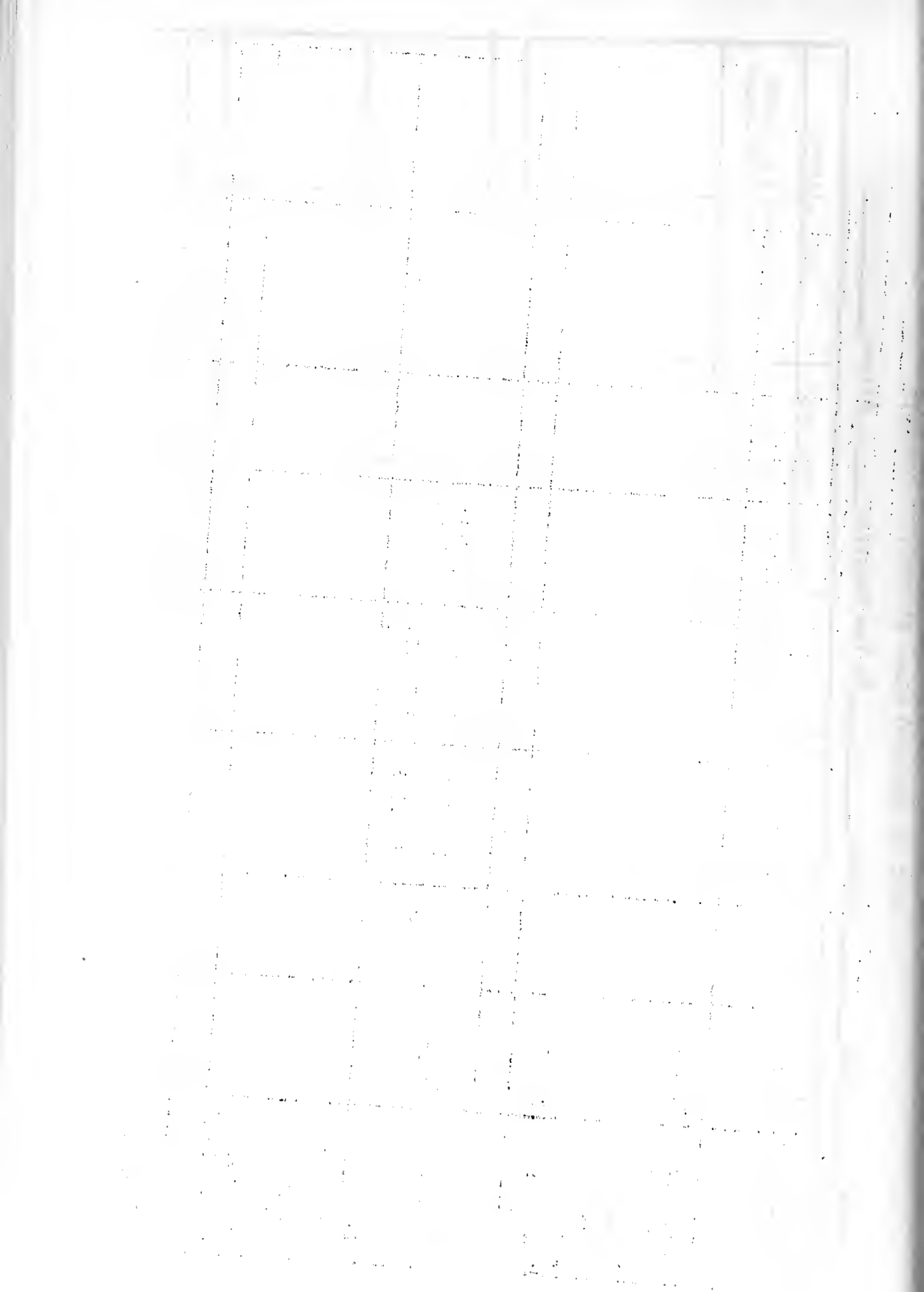


## COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 40' Load 300 ppf Section 16.5"x9" Cu Yds Concrete 1.53 Strand 1-1 1/2"

73

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	12.25	1,099	5,495	\$2470.00	\$12350.	\$ 24.70	\$ 247.00
Strand							16,320.00	163,200.00
Bearing Assembly							349.00	3,460.00
Ready Mix Concrete	Cu. Yd.	11.15	153	1,530			1,709.00	17,090.00
Total-Mat'l.							\$18,402.70	\$183,997.00
ITEM								
Labor					No. Units per Beam			
Carpenters	Hour	17.09	3.5	1.099			\$ 1,186.00	\$ 11,860.00
Common Labor	Hour	11.90	2	1.099			417.00	4,170.00
Structural Iron Worker	Hour	13.25			1/2		162.50	1,625.00
Total-Labor							\$ 1,765.50	\$ 17,655.00
TOTAL							\$20,168.20	\$201,652.00



COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

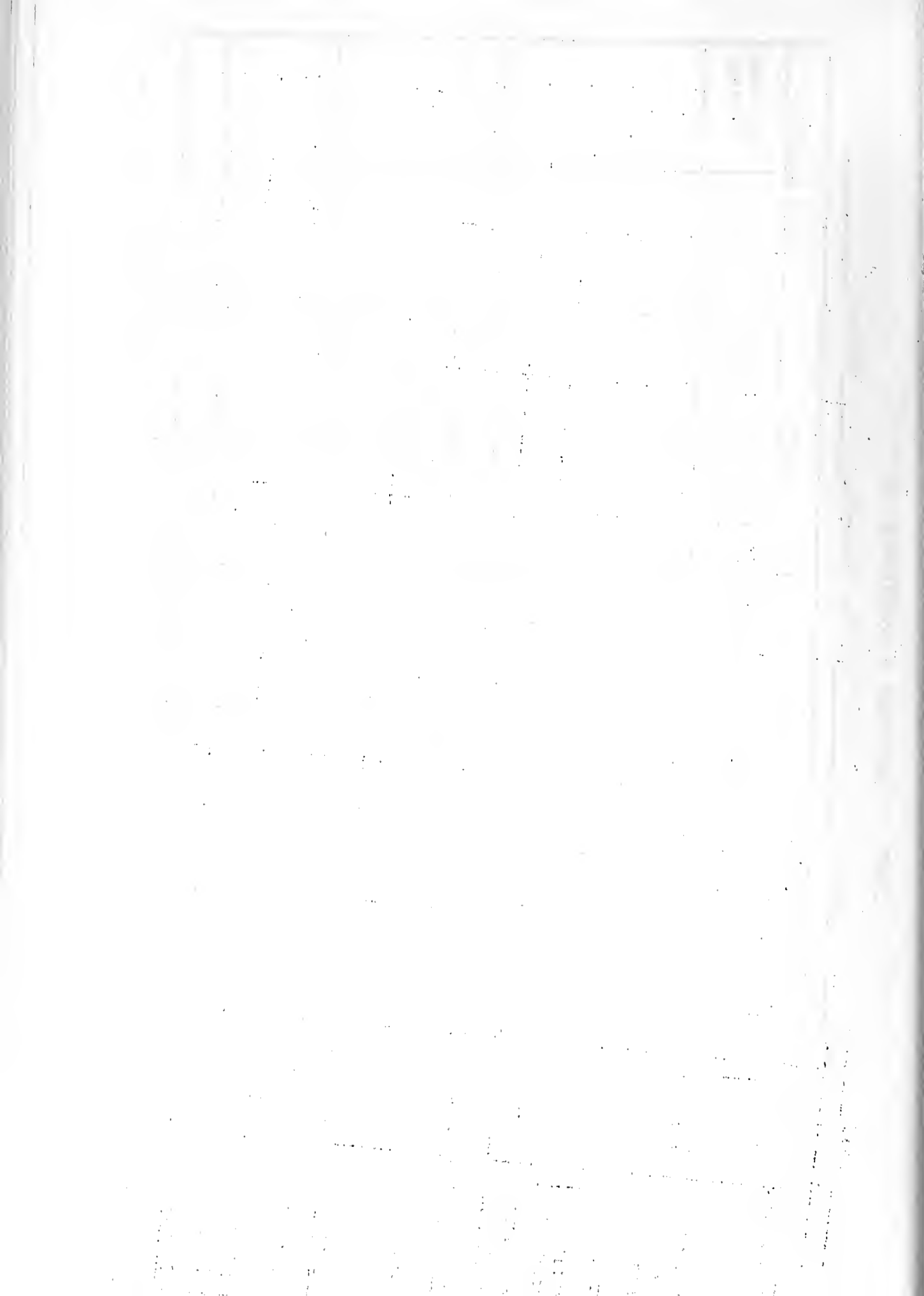
Length 40' Load 400 ppf Section 11.5"x26" Cu Yds Concrete 3.075 Lbs Reinforced Steel 671

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST		COST ALLOWED	
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	\$ .296	211.6	423.2	\$62.60	\$125.20	\$31.30	\$125.20
Reinforcing Bars	Pound	\$ .0879	671	6,710	-	-	59.00	590.00
Ready Mix Concrete	Cu. Yd.	\$11.15	3.075	30.75	-	-	34.25	342.50
Total-Mat'l.							\$124.55	\$1,057.70
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies			
Labor					1 Form	2 Forms		
Carpenter	Hour	9	\$3.09	2.116	1	10	\$58.90	\$589.00
Common Labor	Hour	6.5	\$1.90	2.116	1	10	26.15	261.50
Total-Labor							\$85.05	\$850.50
TOTAL							\$209.60	\$1,908.20

No.	Name	Age	Sex	Remarks
1	John Doe	25	Male	Good
2	Jane Smith	30	Female	Good
3	Bob Johnson	28	Male	Good
4	Alice Brown	22	Female	Good
5	Charlie White	35	Male	Good
6	Diana Green	27	Female	Good
7	Frank Black	32	Male	Good
8	Grace King	29	Female	Good
9	Henry Lee	31	Male	Good
10	Ivy Clark	26	Female	Good
11	Jack Hall	33	Male	Good
12	Karen Young	24	Female	Good
13	Liam Scott	34	Male	Good
14	Mia Adams	23	Female	Good
15	Noah Baker	36	Male	Good
16	Olivia Carter	21	Female	Good
17	Peter Evans	37	Male	Good
18	Quinn Foster	20	Female	Good
19	Ryan Gibson	38	Male	Good
20	Sarah Harris	19	Female	Good
21	Thomas King	39	Male	Good
22	Uma Lee	18	Female	Good
23	Victor Scott	40	Male	Good
24	Wendy Adams	17	Female	Good
25	Xavier Baker	41	Male	Good
26	Yara Carter	16	Female	Good
27	Zoe Evans	42	Female	Good
28	Adam Foster	15	Male	Good
29	Bella Gibson	43	Female	Good
30	Chris Harris	14	Male	Good
31	Dana King	44	Female	Good
32	Ethan Lee	13	Male	Good
33	Fiona Scott	45	Female	Good
34	Gavin Adams	12	Male	Good
35	Hannah Baker	46	Female	Good
36	Ian Carter	11	Male	Good
37	Jessica Evans	47	Female	Good
38	Kyle Foster	10	Male	Good
39	Laura Gibson	48	Female	Good
40	Mason Harris	9	Male	Good
41	Nora King	49	Female	Good
42	Oscar Lee	8	Male	Good
43	Pamela Scott	50	Female	Good
44	Quinn Adams	7	Female	Good
45	Rachel Baker	51	Female	Good
46	Samuel Carter	6	Male	Good
47	Tina Evans	52	Female	Good
48	Umar Foster	5	Male	Good
49	Vera Gibson	53	Female	Good
50	Walter Harris	4	Male	Good
51	Xenia King	54	Female	Good
52	Yusef Lee	3	Male	Good
53	Zoe Scott	55	Female	Good
54	Adam Adams	2	Male	Good
55	Bella Baker	56	Female	Good
56	Chris Carter	1	Male	Good
57	Dana Evans	57	Female	Good
58	Ethan Foster	0	Male	Good
59	Fiona Gibson	58	Female	Good
60	Gavin Harris	59	Male	Good
61	Hannah King	60	Female	Good
62	Ian Lee	61	Male	Good
63	Jessica Scott	62	Female	Good
64	Kyle Adams	63	Male	Good
65	Laura Baker	64	Female	Good
66	Mason Carter	65	Male	Good
67	Nora Evans	66	Female	Good
68	Oscar Foster	67	Male	Good
69	Pamela Gibson	68	Female	Good
70	Quinn Harris	69	Female	Good
71	Rachel King	70	Female	Good
72	Samuel Lee	71	Male	Good
73	Tina Scott	72	Female	Good
74	Umar Adams	73	Male	Good
75	Vera Baker	74	Female	Good
76	Walter Carter	75	Male	Good
77	Xenia Evans	76	Female	Good
78	Yusef Foster	77	Male	Good
79	Zoe Gibson	78	Female	Good
80	Adam Harris	79	Male	Good
81	Bella King	80	Female	Good
82	Chris Lee	81	Male	Good
83	Dana Scott	82	Female	Good
84	Ethan Adams	83	Male	Good
85	Fiona Baker	84	Female	Good
86	Gavin Carter	85	Male	Good
87	Hannah Evans	86	Female	Good
88	Ian Foster	87	Male	Good
89	Jessica Gibson	88	Female	Good
90	Kyle Harris	89	Male	Good
91	Laura King	90	Female	Good
92	Mason Lee	91	Male	Good
93	Nora Scott	92	Female	Good
94	Oscar Adams	93	Male	Good
95	Pamela Baker	94	Female	Good
96	Quinn Carter	95	Female	Good
97	Rachel Evans	96	Female	Good
98	Samuel Foster	97	Male	Good
99	Tina Gibson	98	Female	Good
100	Umar Harris	99	Male	Good
101	Vera King	100	Female	Good

40'      400 ppf      Section      18.5" x 9.5"      Cu Yds Concrete      Strand      1-15"

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST			COST ALLOWED		
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams
Material										
Plywood Forms	S.F.C.S.	\$ .296	155.0	310.0	\$45.80	\$91.60	\$22.90	\$91.60		
Strand										
Bearing Assembly										
Ready Mix Concrete	Cu. Yd.	\$11.15	1.80	18.0						
Total-Mat'l.							\$221.29	\$2,075.50		
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies					
Labor					1 Form	2 Forms				
Carpenter	Hour	9	\$3.09	1.55	1	10	\$43.10	\$431.00		
Common Labor	Hour	65	\$1.90	1.55	1	10	19.12	191.20		
Total-Labor							\$62.22	\$622.20		
TOTAL							\$283.51	\$2,697.70		



## COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

76

Length 40' Load 400 pps Section 11.5"x26" Cu Yds Concrete 3.075 Lbs Reinforced Steel 671

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	1,734	8,670	\$3900.00	\$19500.00	\$ 39.00	\$ 390.00
Reinforcing Bars	Pound	\$ .0844	67,100	671,000	-	-	5,665.00	56,650.00
Ready Mix Concrete	Cu. Yd.	\$11.15	307.5	3,075	-	-	3,430.00	34,300.00
Total-Mat'l.							\$ 9,134.00	\$ 91,340.00
Labor								
	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams		
Carpenters	Hour	\$3.09	3.5	1.734	-	-	\$ 1,873.00	\$ 18,730.00
Common Labor	Hour	\$1.90	2	1.734	-	-	659.00	6,590.00
Structural Iron Worker	Cwt. of Steel	\$1.95	-	-	671	6,710	1,309.00	13,090.00
Total-Labor							\$ 3,841.00	\$ 38,410.00
TOTAL							\$12,975.00	\$129,750.00





**COST OF 100-1000 BEAMS PRESTRESSED CONCRETE**

Length 40' Load 400 lb Section 15.5"x19.5" Cu Yds Concrete 1.80 Strand 1-15"

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material	Purchased Steel Forms							
	Strand	\$2.25	1,235	6,175	\$2780.00	\$13900.	\$ 27.80	\$ 278.00
	Bearing Assembly						17,370.00	173,700.00
	Ready Mix Concrete	\$11.15	180	1,800			459.00	4,560.00
							2,010.00	20,100.00
Total-Mat'l.							\$19,864.80	\$198,638.00
Labor								
	Carpenters	\$7.09	3.5	1.235	No. Units per Beam		\$ 1,334.00	\$ 13,340.00
	Common Labor	\$1.00	2	1.235			469.00	4,690.00
	Structural Iron Worker	\$3.25			1/2		162.50	1,625.00
	Total-Labor						\$ 1,965.50	\$ 19,655.00
TOTAL							\$21,832.30	\$218,293.00



# COST OF 1-10 BEAMS - CONVENTIONAL REINFORCED CONCRETE

Length 40' Load 500 psf Section 13" x 28" Cu Yds Concrete 3.74 Lbs Reinforced Steel 728

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST		COST ALLOTTED	
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam	(2 Forms) 10 Beams
Material								
Plywood Forms	S.F.C.S.	\$ .296	230	460	\$68.10	\$136.20	\$ 34.05	\$ 136.20
Reinforcing Bars	Pound	\$ .0879	728	7,280	-	-	64.05	640.50
Ready Mix Concrete	Cu. Yd.	\$11.15	3.74	37.4	-	-	41.70	417.00
Total-Mat'l.							\$139.80	\$1,193.70
ITEM	Unit	No. Units per 100 S.F.C.S. per Beam	Cost per Labor Unit	No. of 100 S.F.C.S. per Beam	No. Assemblies & Disassemblies			
					1 Form	2 Forms		
Labor								
Carpenter	Hour	9	\$3.09	2.298	1	10	\$ 63.80	\$ 638.00
Common Labor	Hour	6.5	\$1.90	2.298	1	10	28.40	284.00
Total-Labor							\$ 92.20	\$ 922.00
TOTAL							\$232.00	\$2,115.70

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1

# COST OF 1-10 BEAMS - PRESTRESSED CONCRETE

79

Length 40' Load 500 ppf Section 20"x10" Cu Yds Concrete 2.06 Strand 2-1 1/4"

ITEM	Unit	Unit Cost	No. Units 1 Beam	No. Units (2 Forms) 10 Beams	COST		
					(1 Form) 1 Beam	(2 Forms) 10 Beams	(1 Form) 1 Beam
Material							
Flywood Forms	S.F.C.S.	\$1.296	166.7	333.3	\$49.30	\$98.60	\$24.65
Strand							
Bearing Assembly							
Ready Mix Concrete	Cu. Yd.	\$11.15	2.06	20.6			
Total-Mat'l.							
ITEM							
Labor							
Carpenter	Hour	9	\$3.09	1.667	1	10	\$46.30
Common Labor	Hour	6.5	\$1.90	1.667	1	10	20.55
Total-Labor							
TOTAL							

TOTAL

\$3,249.00

\$668.50

\$66.85

\$205.50

\$20.55

\$463.00

\$46.30

No. Assemblies  
& Disassemblies

No. of  
100  
S.F.C.S.  
per Beam

Cost per  
Labor  
Unit

No. Units  
per 100  
S.F.C.S.  
per Beam

Unit

20.6

2.06

\$11.15

\$2,178.00

\$217.80

\$74.10

\$7.41

\$229.80

\$22.98

\$2,580.50

\$272.84

\$98.60

\$24.65

COST ALLOWED

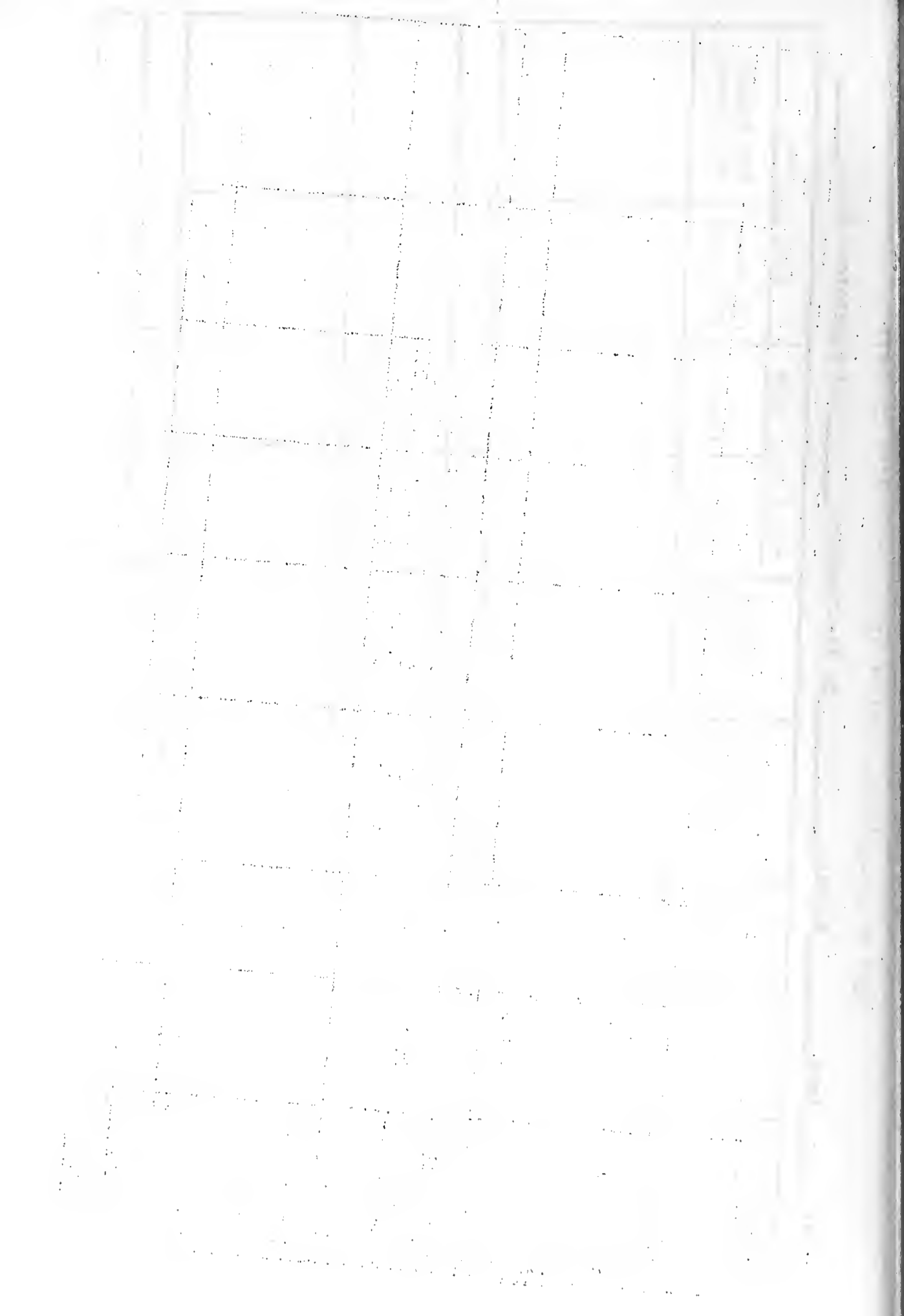


# COST OF 100-1000 BEAMS CONVENTIONAL REINFORCED CONCRETE

80

Length 40' Load 500 ppf Section 13" x 28" Cu Yds Concrete 3.74 Lbs Reinforced Steel 728

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	1,867	9,335	\$4,200	\$21,000	\$ 42.00	\$ 420.00
Reinforcing Bars	Pound	\$ .0844	72,800	728,000	-	-	6,150.00	61,500.00
Ready Mix Concrete	Cu. Yd.	\$11.15	374	3,740	-	-	4,170.00	41,700.00
Total-Mat'l.							\$10,362.00	\$103,620.00
ITEM	Unit	Unit Cost	No. Units per 100 S.F.C.S.	No. of 100 S.F.C.S. per Beam	Cwt. of Steel for 100 Beams	Cwt. of Steel for 1000 Beams		
Labor								
Carpenters	Hour	\$3.09	3.5	1.867	-	-	\$ 2,015.00	\$ 20,150.00
Common Labor	Hour	\$1.90	2	1.867	-	-	708.00	7,080.00
Structural Iron Worker	Cwt. of Steel	\$1.95	-	-	728	7,280	1,420.00	14,200.00
Total-Labor							\$ 4,143.00	\$ 41,430.00
TOTAL							\$14,505.00	\$145,050.00





# COST OF 100-1000 BEAMS PRESTRESSED CONCRETE

Length 40' Load 500 ppf Section 20" x 10" Cu Yds Concrete 2.06 Strand 2-14

ITEM	Unit	Unit Cost	No. Units (10 Forms) 100 Beams	No. Units (50 Forms) 1000 Beams	TOTAL FORM COST		COST ALLOWED	
					10 Forms	50 Forms	(10 Forms) 100 Beams	(50 Forms) 1000 Beams
Material								
Purchased Steel Forms	S.F.C.S. per form	\$2.25	1,334	6,670	\$3000.00	\$15,000.	\$ 30.00	\$ 300.00
Strand							21,780.00	217,800.00
Bearing Assembly							741.00	7,380.00
Ready Mix Concrete	Cu. Yd.	\$11.15	206	2,060			2,298.00	22,980.00
Total-Mat'l.							\$24,849.00	\$248,460.00
ITEM								
Labor					No. Units per Beam			
Carpenters	Hour	\$3.09	3.5	1.334			\$ 1,440.00	\$ 14,400.00
Common Labor	Hour	\$1.00	2	1.334			507.00	5,070.00
Structural Iron Worker	Hour	\$3.25			1		325.00	3,250.00
Total-Labor							\$ 2,272.00	\$ 22,720.00
TOTAL							\$27,121.00	\$271,180.00



# PLCOT OF TOTAL LABOR COST 20' BEAMS

Values on curves indicate  
applied live load in ppi

— Conventional Beams  
- - - Prestressed Beams

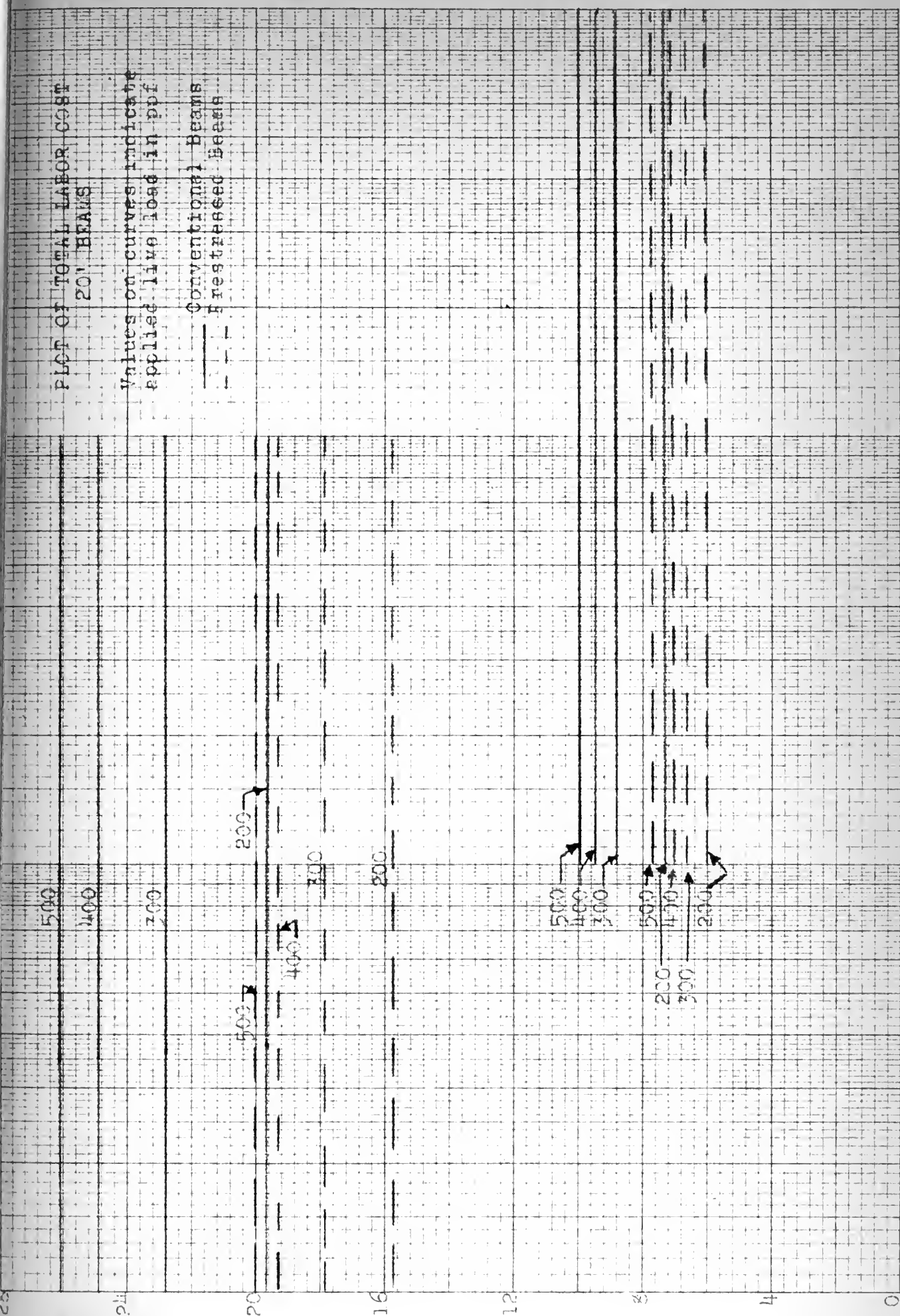
Unit Cost - Dollars

Total Number of Beams Poured in Job

1000

10

1



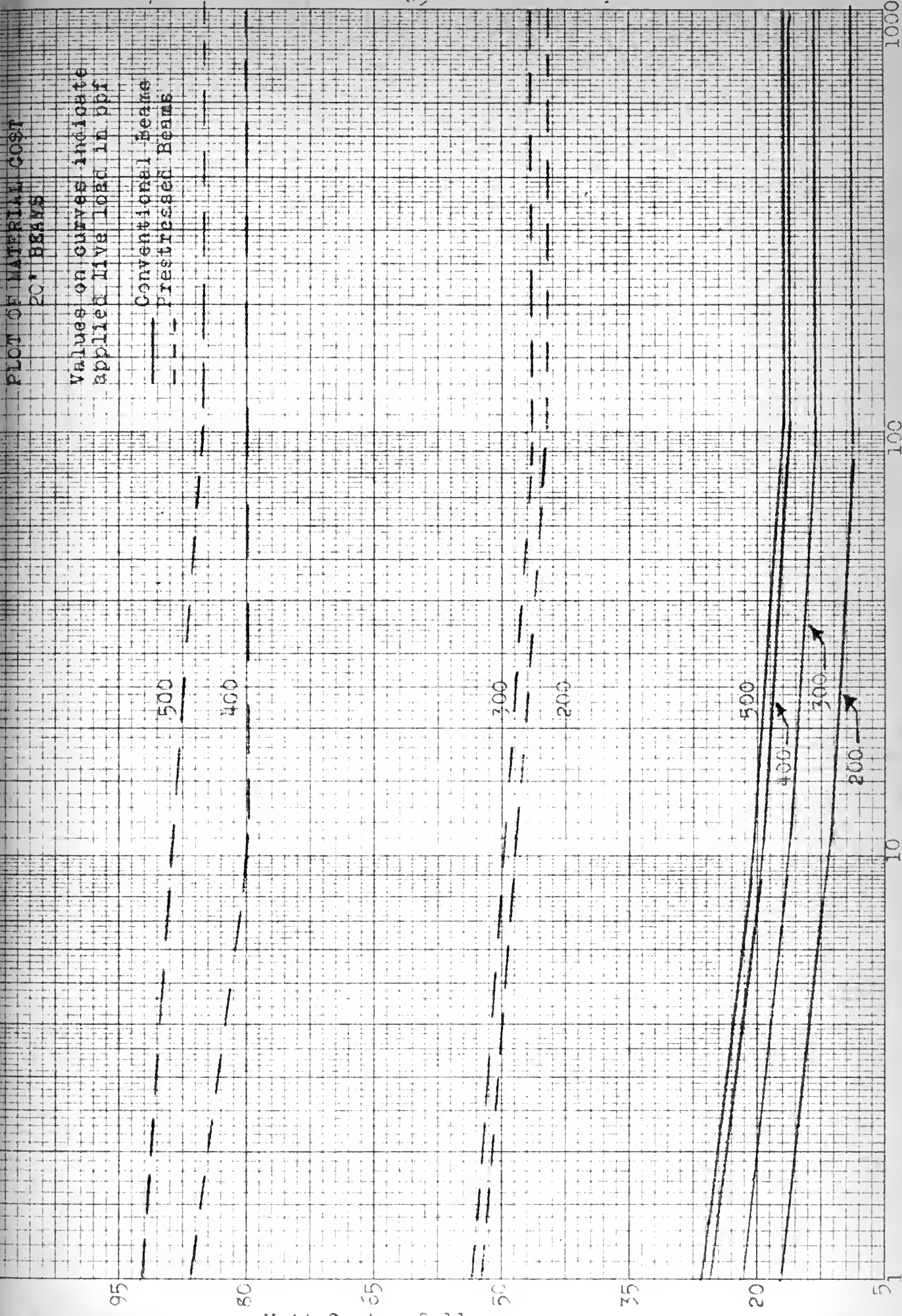


PLOT OF MATERIAL COST

20" BEAMS

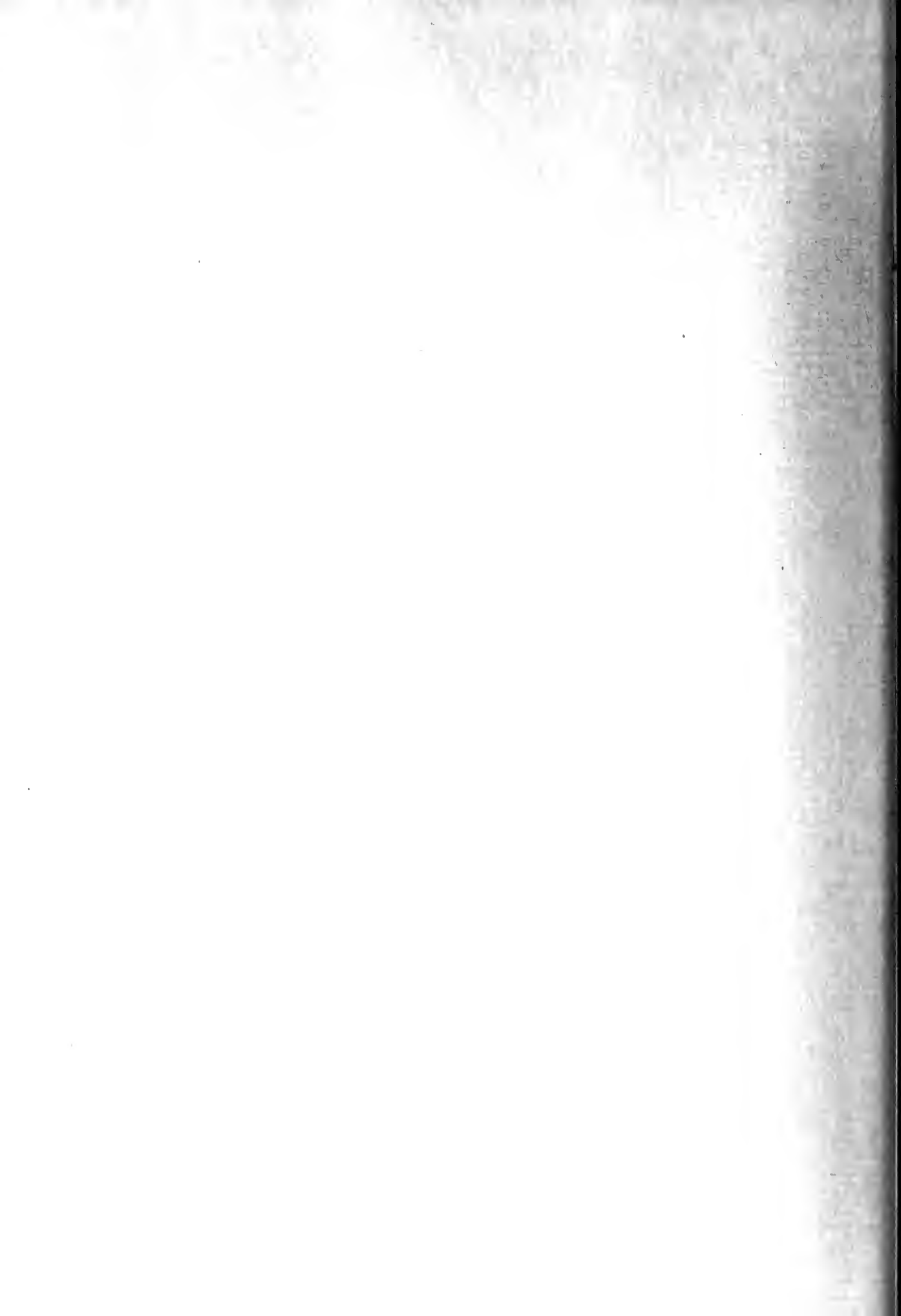
Values on curves indicate  
applied live load in ppi

— Conventional Beams  
- - - Prestressed Beams



Unit Cost - Dollars

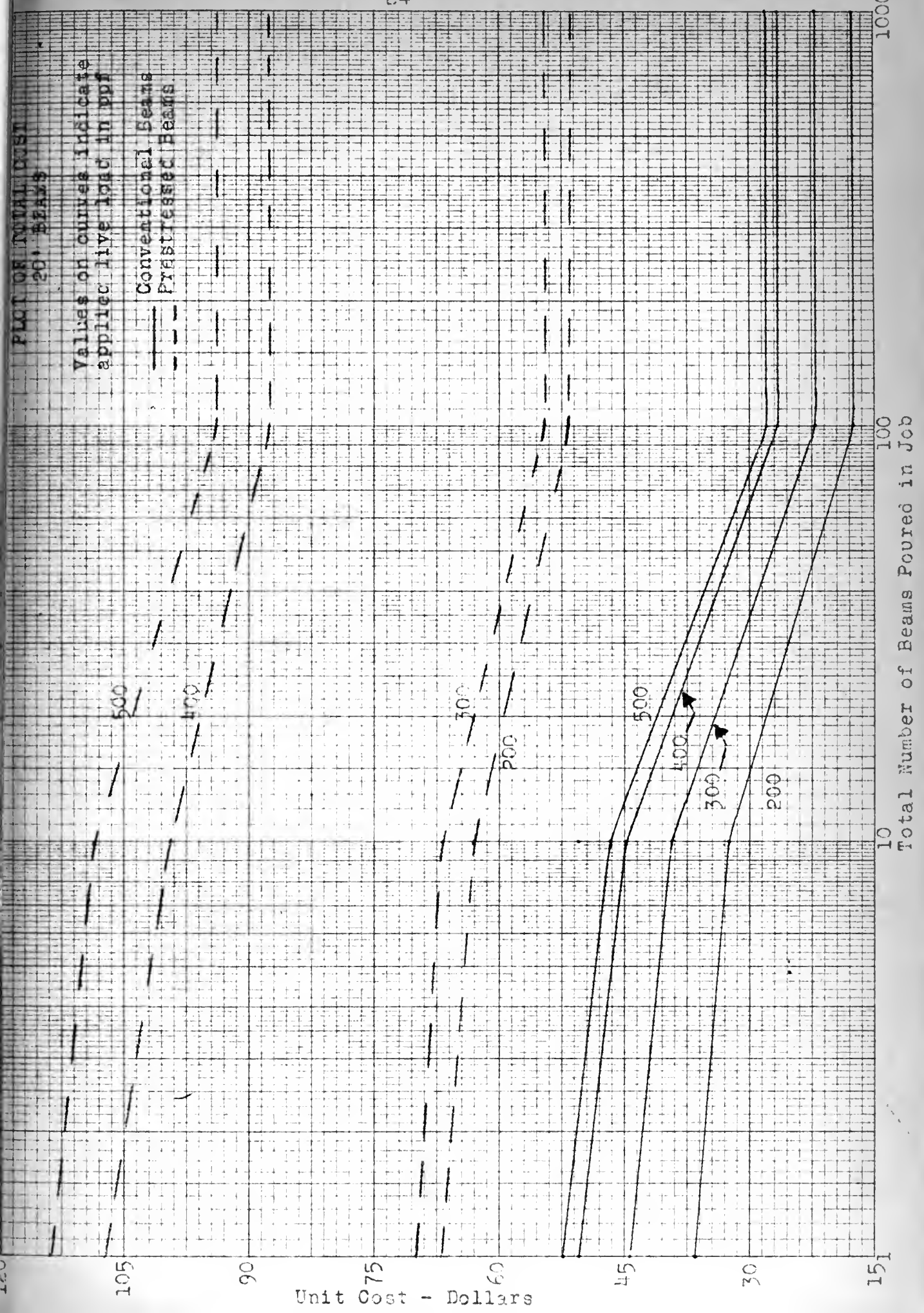
Total Number of Beams Poured in Job



PLOT OR TOTAL COST  
20' BEAMS

Values on curves indicate  
applied live load in kpl

— Conventional Beams  
--- Prestressed Beams



Total Number of Beams Poured in Job

Unit Cost - Dollars







Plot of Total Labor Cost  
for Beams

Values on curves indicate  
applied live load in ppf

— Conventional Beams  
- - - Prestressed Beams

Unit Cost - Dollars

Total Number of Beams Fouled in Job

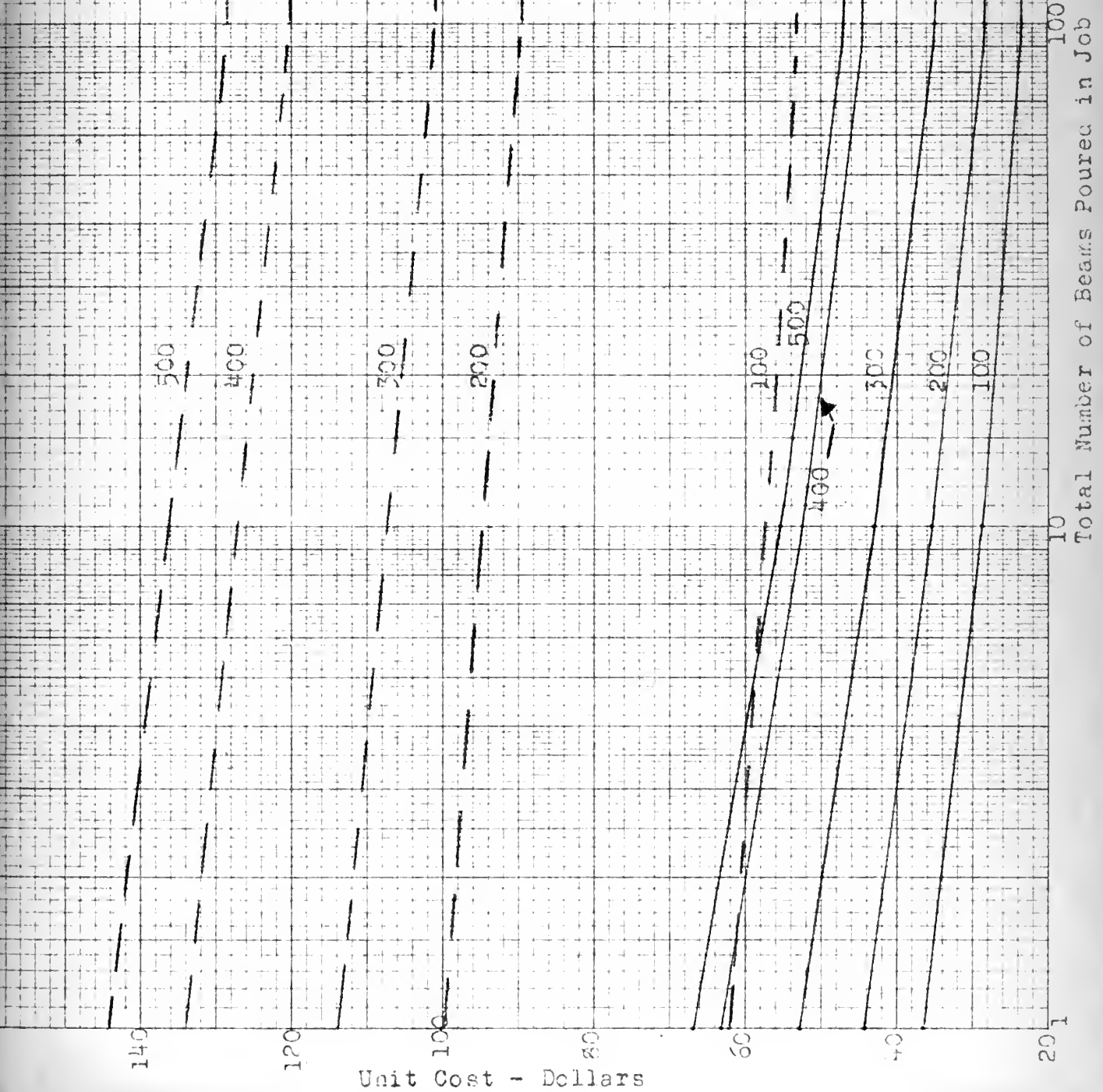


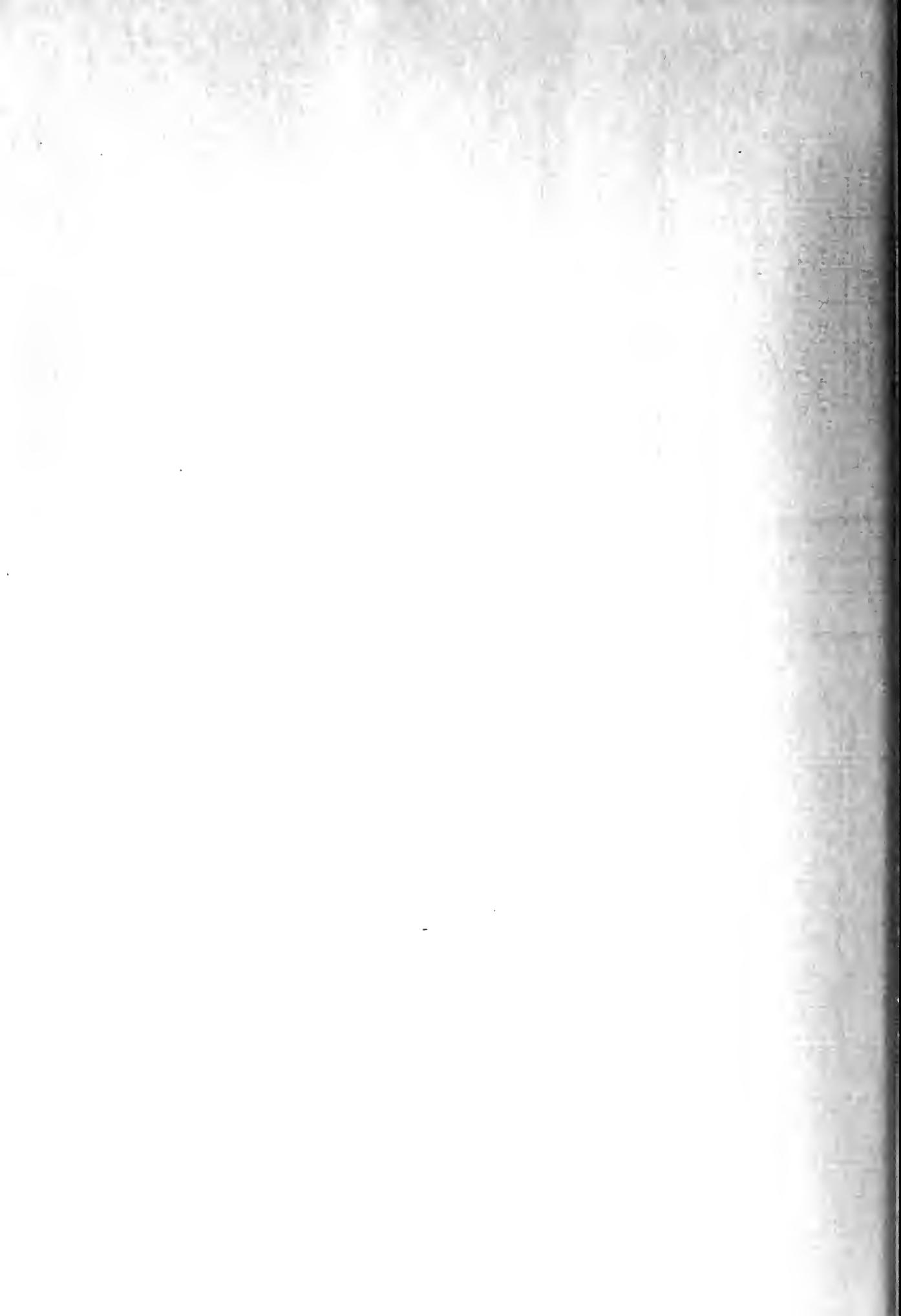


PLOT OF MATERIAL COST  
30' BEAMS

Values on curves indicate  
applied live load in pbf

— Conventional Beams  
--- Prestressed Beams





PLOT OF TOTAL COST  
30 BEAMS

Values on curves indicate  
applied live load in kpf

— Conventional Beams  
--- Prestressed Beams

175

150

125

100

75

50

25

Unit Cost - Dollars

500

400

300

200

500

400

300

200

100

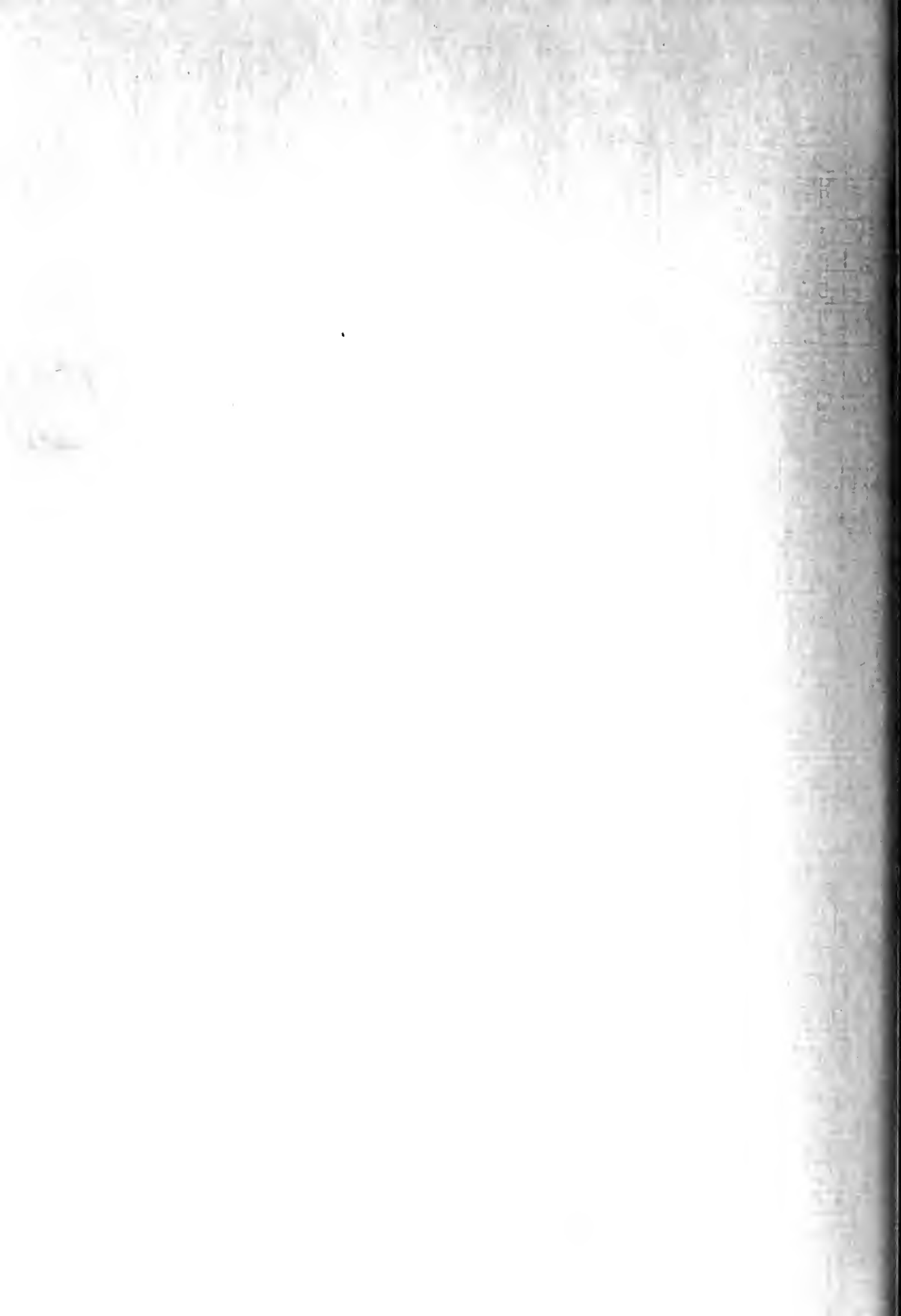
10

100

1000

Total Number of Beams Poured in Job

200





PLOT OF TOTAL LABOR COST

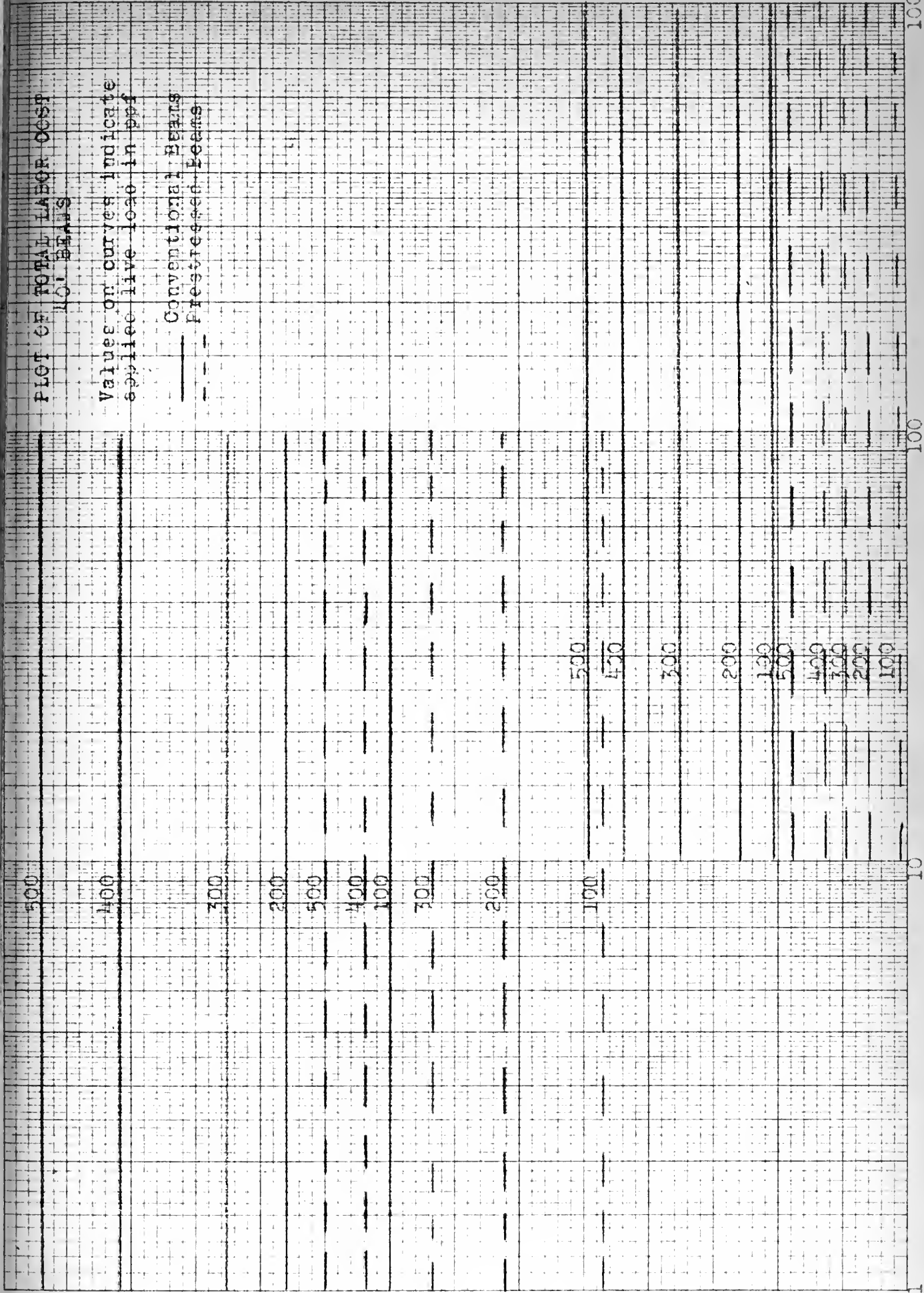
10' BEAMS

Values on curves indicate applied live load in psf

— Conventional Beams  
- - - Prestressed Beams

Unit Cost - Dollars

Total Number of Beams Poured in Job







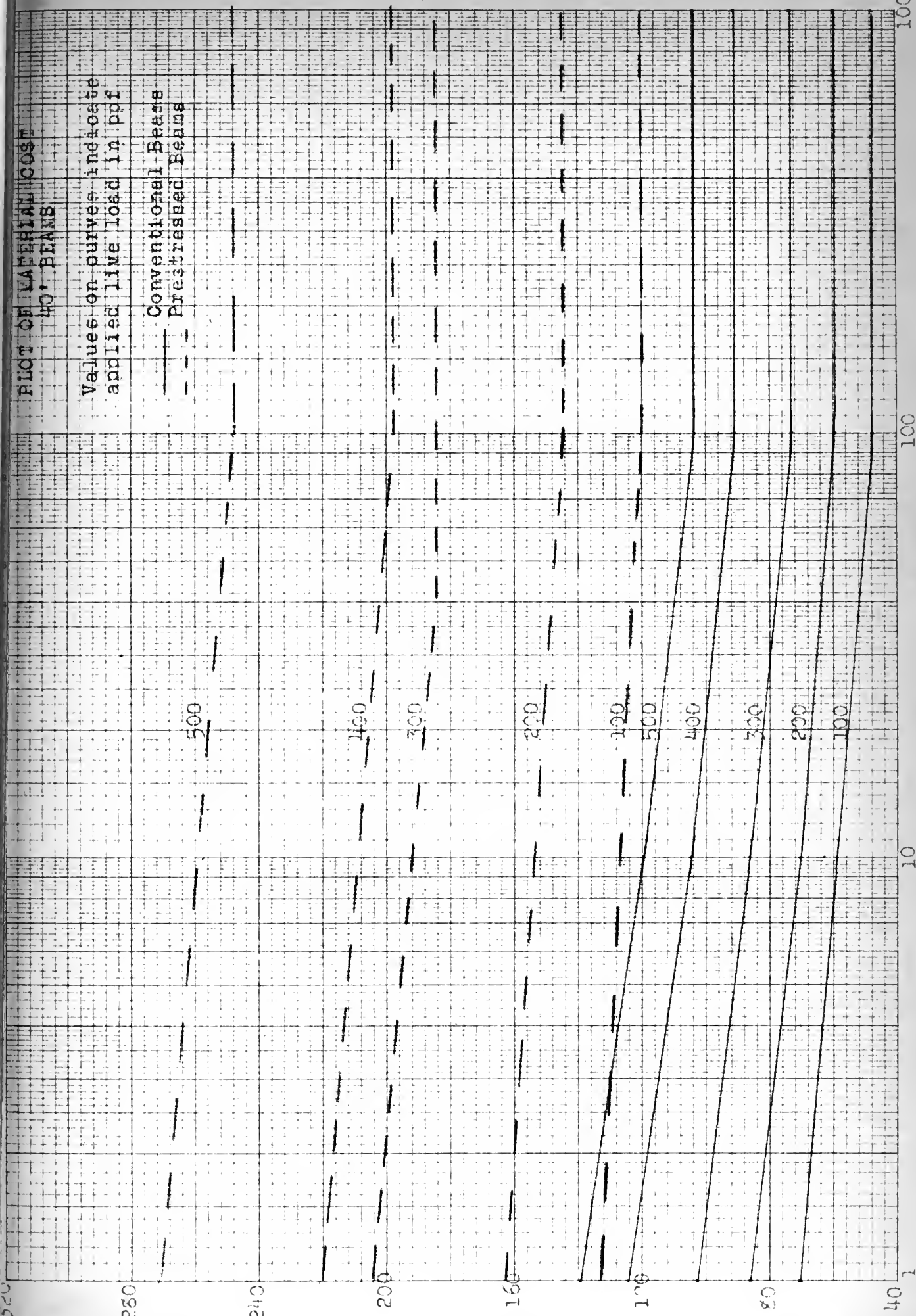
# PLOT OF MATERIAL COST 40" BEAMS

Values on curves indicate  
applied live load in pcf

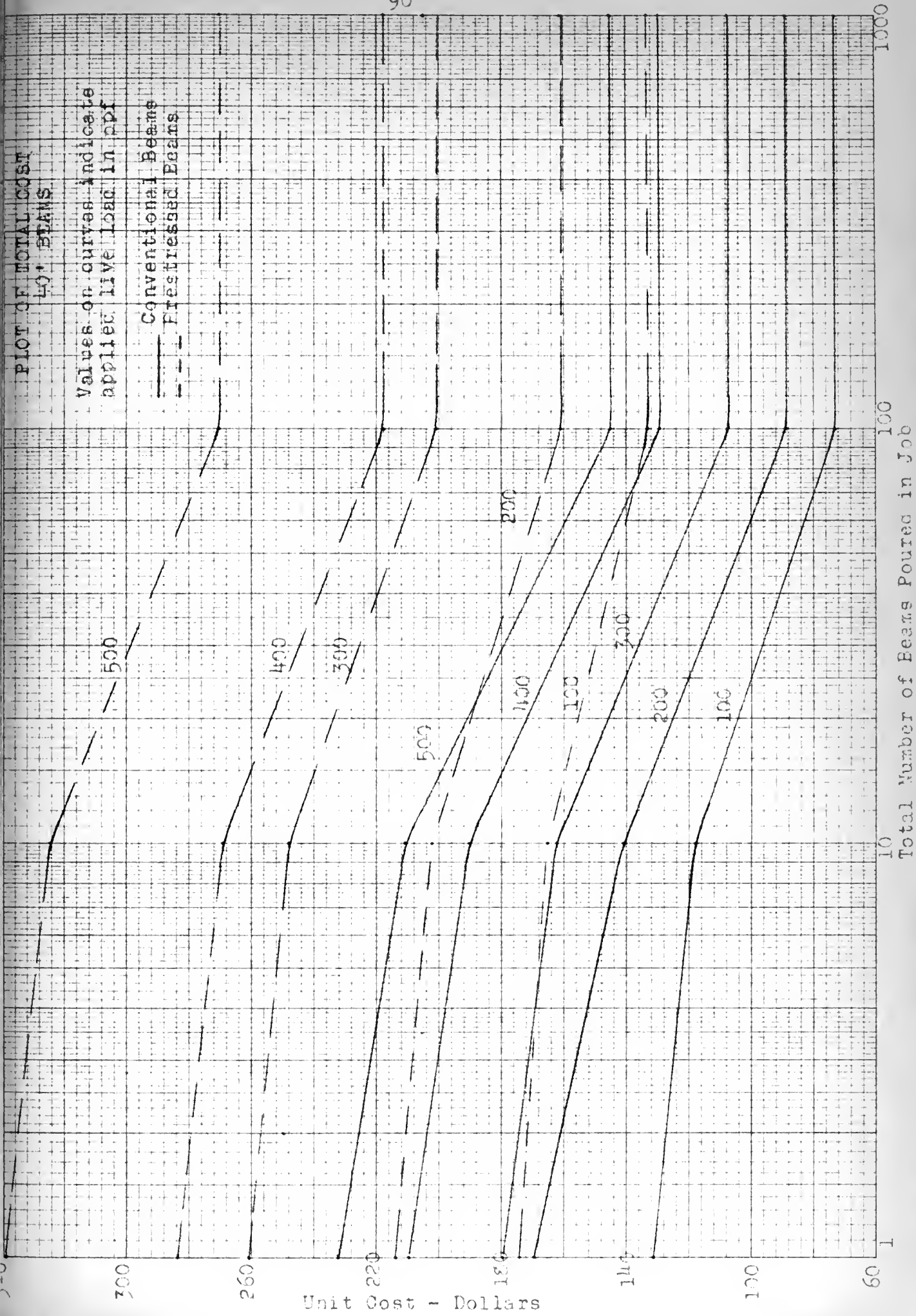
— Conventional Beams  
- - - Prestressed Beams

Unit Cost - Dollars

Total Number of Beams Poured in Job







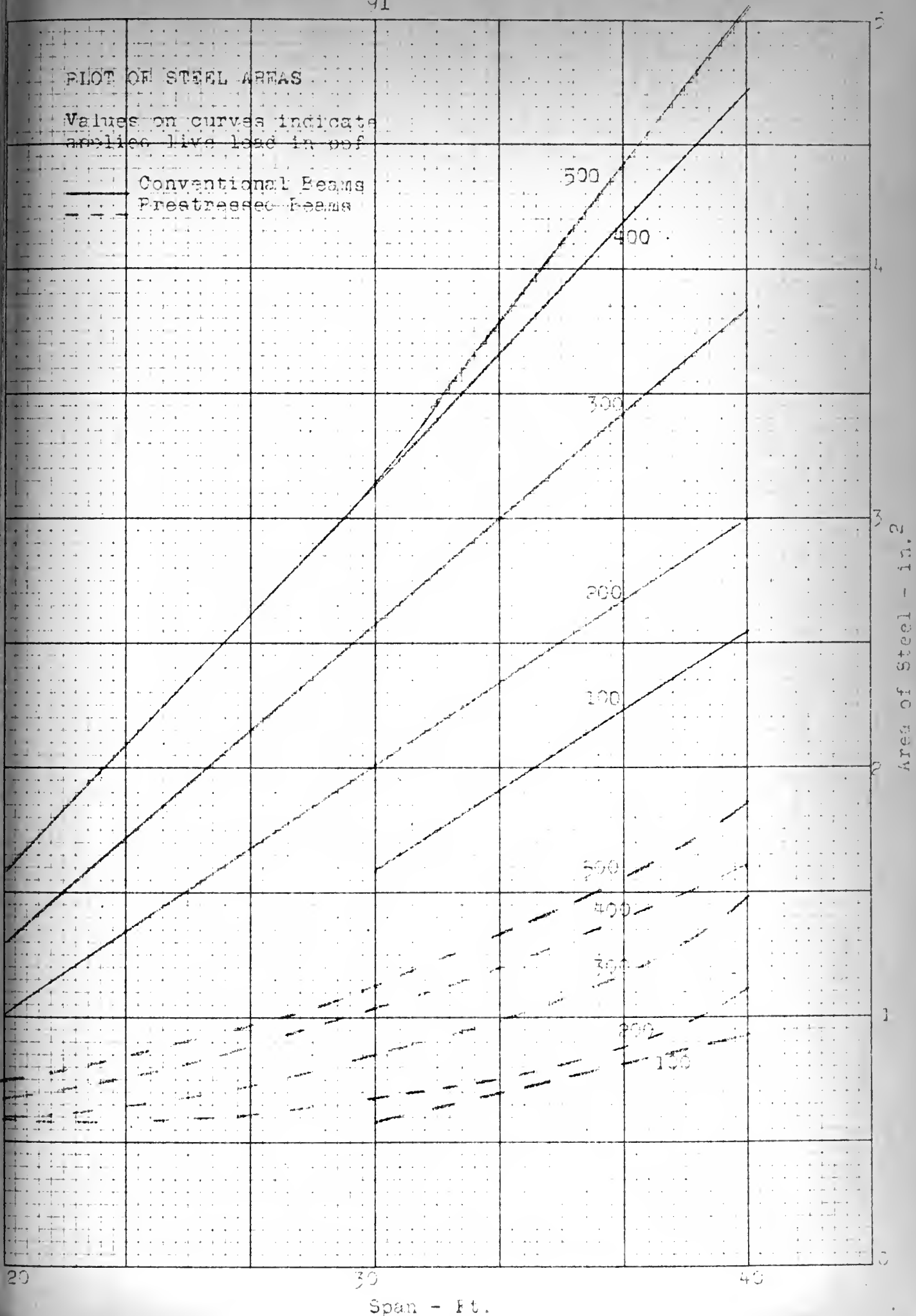


# PLOT OF STEEL AREAS

Values on curves indicate  
applied live load in psf

— Conventional Beams  
- - - Prestressed Beams

Area of Steel - in.<sup>2</sup>

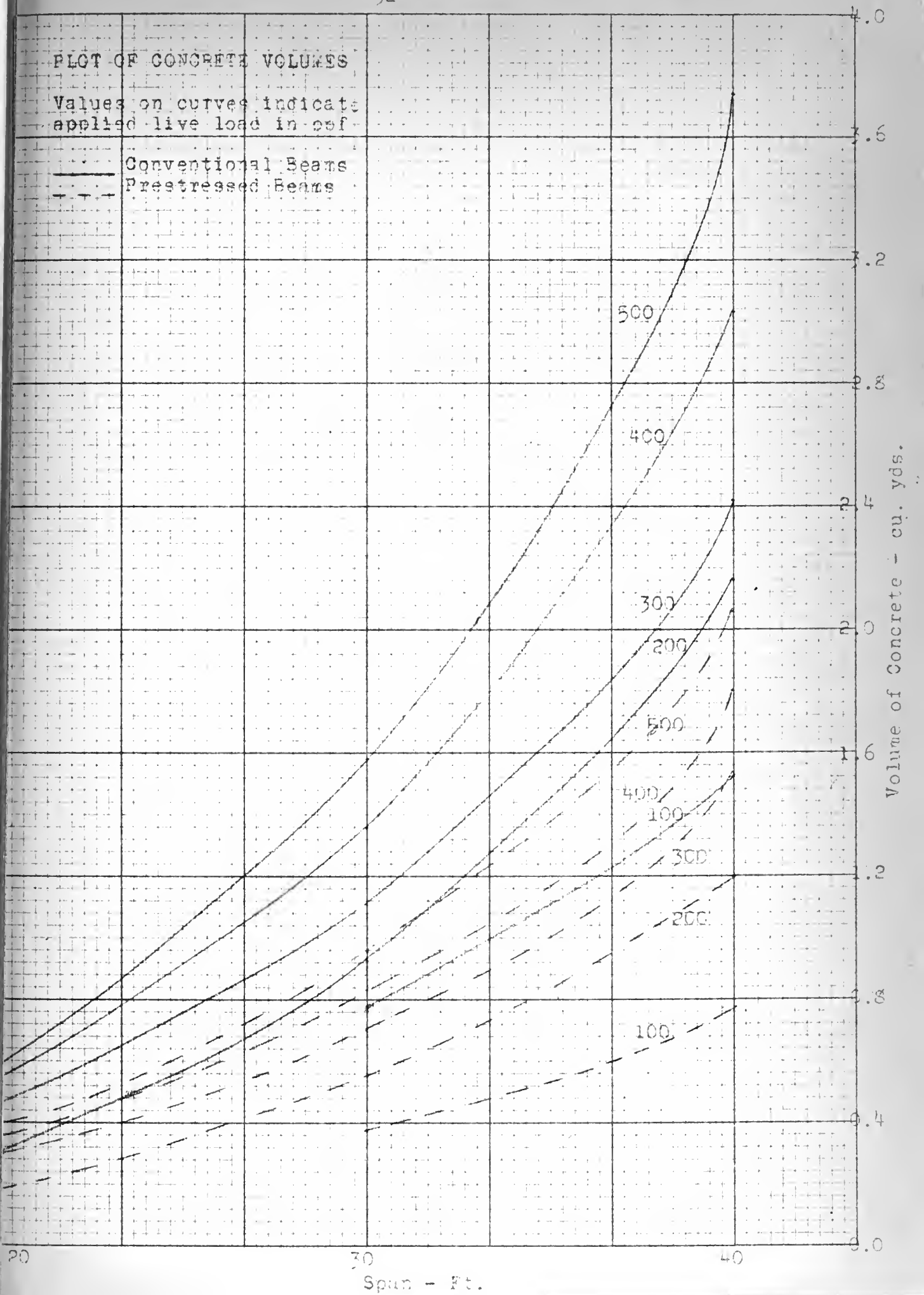


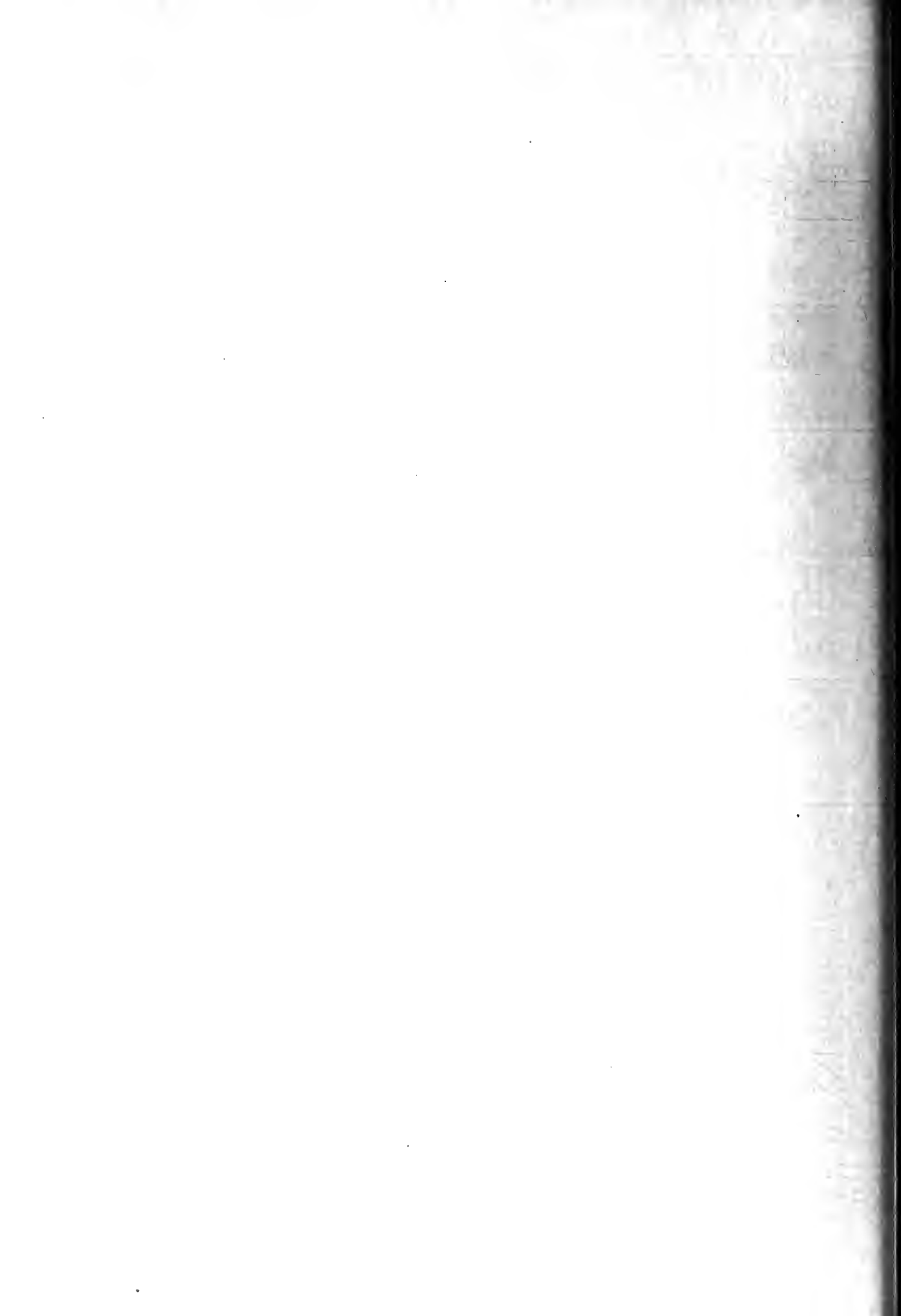


# PLOT OF CONCRETE VOLUMES

Values on curves indicate  
applied live load in psf

— Conventional Beams  
- - - Prestressed Beams







## CONCLUSIONS

From the comparison of the fourteen simple beams, conventional reinforced concrete is more economical in total cost. Prestressed concrete is more economical in labor cost and quantities of concrete and steel.

Despite the fact that less steel and concrete were used in the prestressed beams, the total cost was greater because of the cost of the prestressing strand.

Prestressed concrete compares more favorably at 40 feet than at 20 feet. It can be reasonably assumed that it will become more favorable as the spans increase and at some span will become more economical than conventional concrete in total cost.

At this time there is a very small demand for prestressing strands. When this demand has become large enough to allow mass production, the strands will become cheaper and, therefore, prestressed concrete will compare economically at shorter spans.



## PART II

## COMPARISON OF A SMALL HIGHWAY BRIDGE

A prestressed concrete bridge in Madison County, Tennessee, was chosen for comparison with a conventional design because it was the first prestressed concrete bridge completed in this country.

The prestressed design consists of three simple beam spans supported on timber pile bents. There are two 20 ft. spans and one 30 ft. span. The beams are unique because they are made up of precast concrete blocks with special end blocks for anchoring the prestressing strand. Each 20 ft. span has one strand and each 30 ft. span has two strands. The concrete blocks have three rectangular holes through which the strands are passed (8).

For the details of the fabrication and the placing of the beams on the bents, the following is quoted from Reference 9:

"... All materials used in the beams, including manufactured concrete block, prestressing cable units, terminals and end plates, were delivered at the yard. Blocks were stacked to facilitate fabrication and cut hand carry distance. There were a total of forty-five beams, built by nine men (2 convicts), organized in two crews with one man placing

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34

cables for both crews. Bridge lumber was used to lay eleven beds upon which beams were built. Beams were built in stacks of four beams, one on top of the other. First, the end block was laid on the bed. Next, a standard block was mortared and set in place against the end block. While each block was being placed, others were being mortared and made ready for use. As construction of each beam progressed, cables were threaded. The beam was completed with another end block. End Plates were put on the cable terminals and nuts tightened slightly. Prestressing was not done until after the initial set of the mortar. Each beam was built in the above manner. Prestressing was done with a calibrated hydraulic jack and rig. Each beam was stressed in about five minutes, by three men.

"During, and prior to the construction of the beams, abutments were poured, piling driven and caps placed. Piling and caps were of creosoted timber. The abutments consist of a concrete cap and end wall, supported on creosoted timber caps, driven through the approach fills. The bridge has a length of seventy-feet, consisting of three spans, placed 20 feet, 30 feet and 20 feet.

"After the completion of the beams in the yard, they were transported to the site on trucks and trailers. They were loaded on the trucks with the truck mounted crane.



The trucks used were two single log trailers, with 2 ton tractors and one equipment trailer, or low-boy. Loading and hauling was no problem.

"At the bridge site the beams were unloaded by the truck-crane and placed directly on the supports to avoid excessive handling and save time. The beams were placed against each other to form a solid deck. The spans were erected successively and as the first span was completed, the crane was backed upon it and the second span laid. The third span was placed in the same manner. The only problem arising in this phase was the necessity to move the crane off the bridge beside the transport truck, pick up a beam then move back on the bridge to place the beam. The capacity of the truck-crane would not allow booming around to pick up and place beams. Although this took some time to make these moves, it, at the same time, furnished a good test for the beams, as the rear axle load of the crane was 25,000 lbs., load with a 30' beam. This exceeds the E-15-44 design load, without the concrete deck in place. Of course the deck will distribute live load and increase the capacity of the bridge.

"After placing the beams, forms were placed for the curbs and end walls. A three inch concrete deck reinforced with 6x6x6/6 wire mesh was poured directly on the beams..."





"... Total construction time took seven days and as high-early cement was used in the deck, the bridge was opened to traffic in ten days."

The conventional design is a simple span stringer bridge with a reinforced concrete deck. This design was used by the authors because it is the type of bridge that would have been built on this site if the prestressed design had not been accepted (9). A drawing on page 105 indicates another solution to this design problem. In the design which follows, the AASHO specifications were used.

The first part of the paper is devoted to a discussion of the general principles of the theory of the structure of the atom. It is shown that the structure of the atom is determined by the laws of quantum mechanics, and that the structure of the atom is determined by the laws of quantum mechanics.

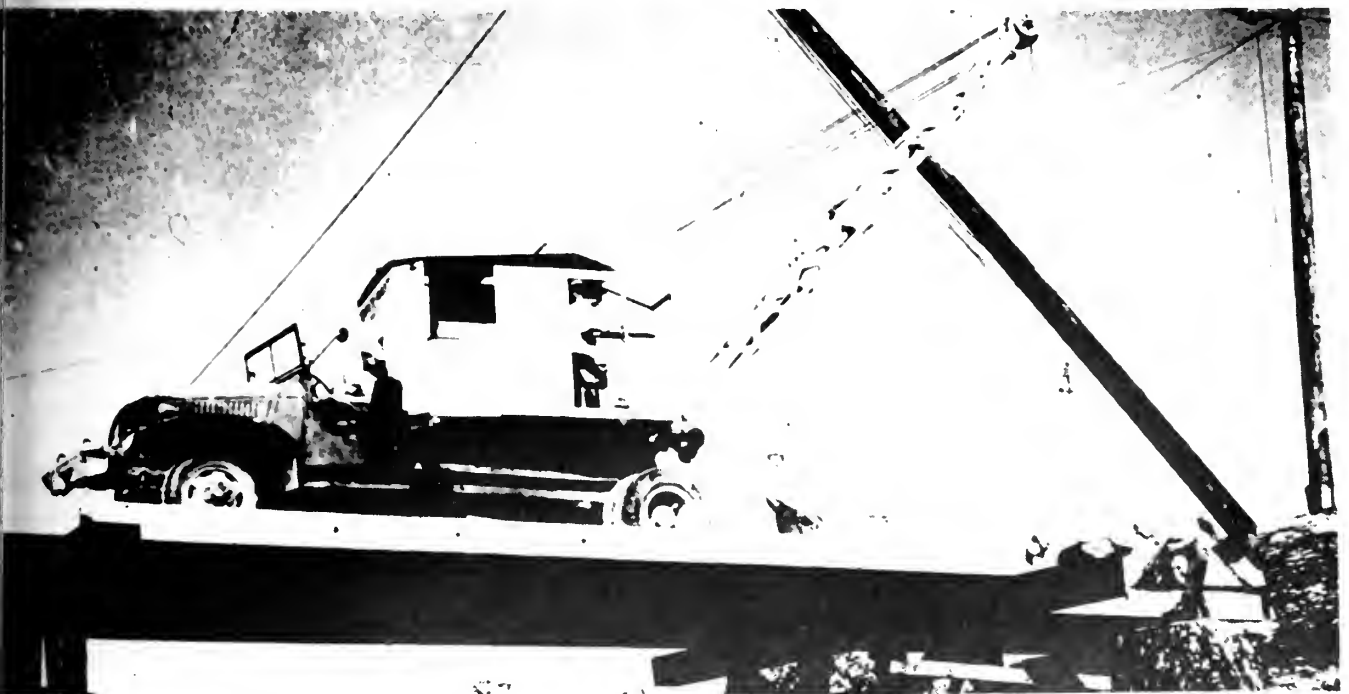
The second part of the paper is devoted to a discussion of the general principles of the theory of the structure of the atom. It is shown that the structure of the atom is determined by the laws of quantum mechanics, and that the structure of the atom is determined by the laws of quantum mechanics.

The third part of the paper is devoted to a discussion of the general principles of the theory of the structure of the atom. It is shown that the structure of the atom is determined by the laws of quantum mechanics, and that the structure of the atom is determined by the laws of quantum mechanics.

The fourth part of the paper is devoted to a discussion of the general principles of the theory of the structure of the atom. It is shown that the structure of the atom is determined by the laws of quantum mechanics, and that the structure of the atom is determined by the laws of quantum mechanics.



CONCRETE BLOCKS prestressed with a hydraulic jack (left) form beams 20 and 30 ft long. Placed side by side . . .

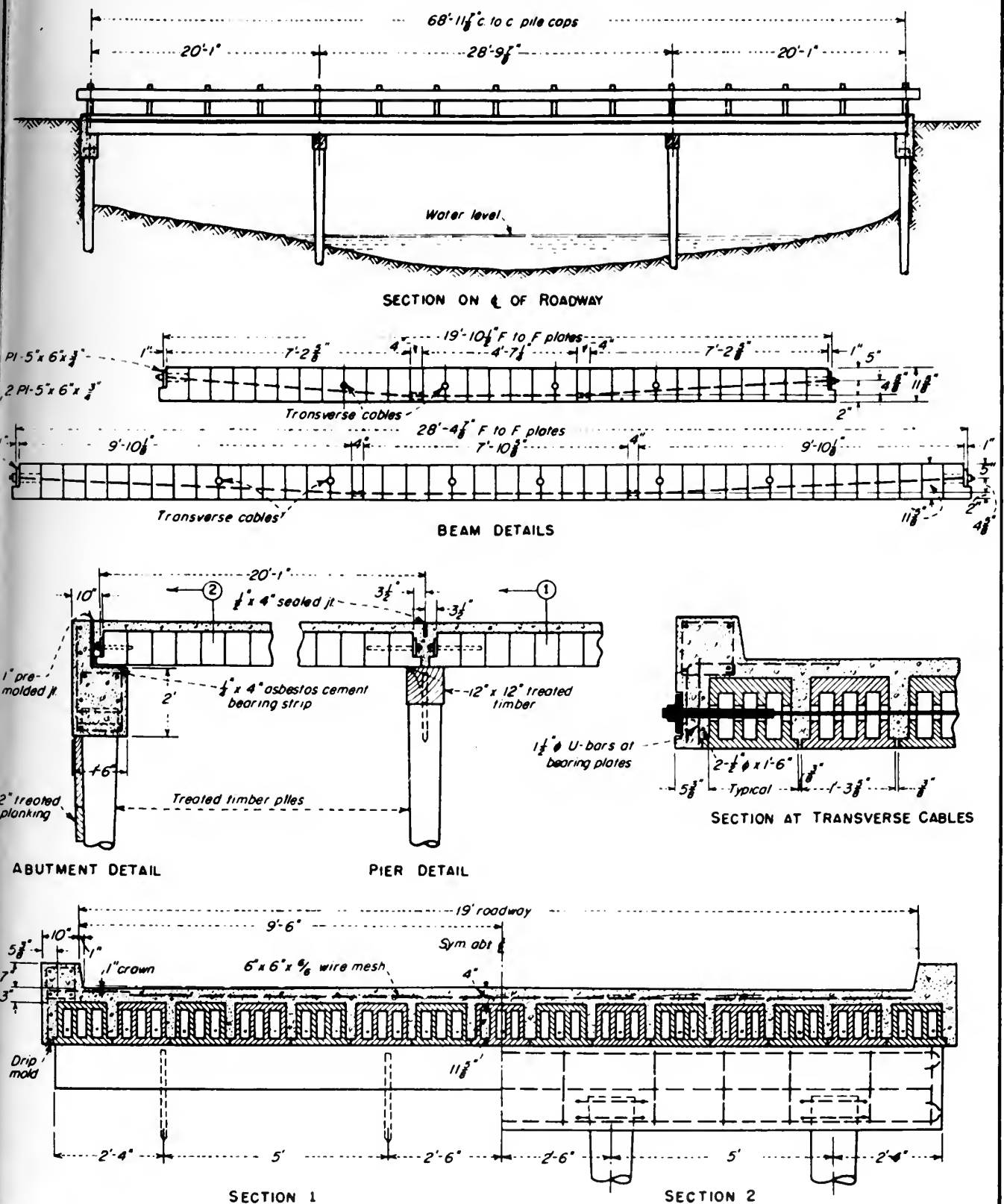


CONCRETE BEAMS comprise a three-span bridge capable of safely sustaining H 10-44 loading or one H 15 truck.

From Engineering News-Record

January 18, 1951

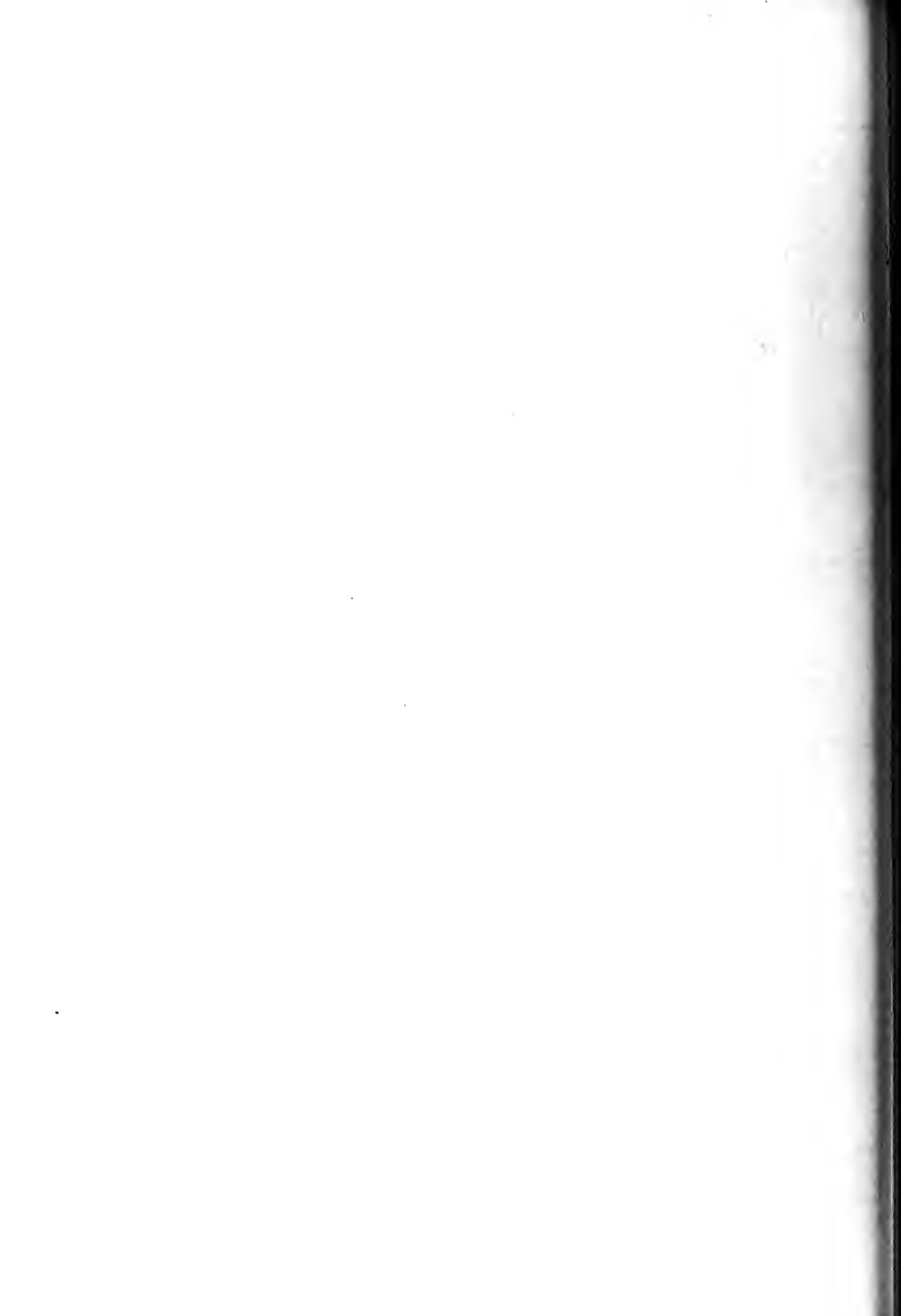


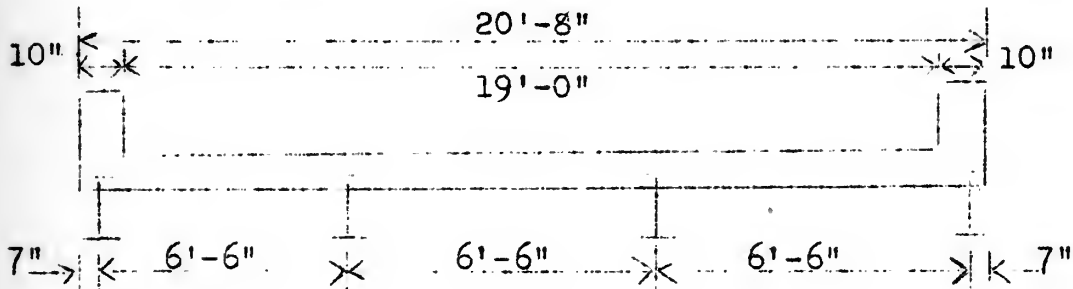


BRIDGE is made up of 45 block beams, 15 per span. Transverse prestressing ties beams together in each span.

From Engineering News-Record

January 18, 1951



Conventional Design Computations

Specifications - AASHO - 1949

Two spans 20'1", one span 28'9 $\frac{7}{8}$ "

Live load - H10-44 or one H15 truck

Floor Slab Design:

Assume 8" flange

$$\text{Span} = 6'6" - 8" + 4" = 6'2"$$

AASHO 3.3.2

Estimate of DL of span

Assume total  $t = 7"$

structural  $t = 10"$

$$w = \frac{10}{12} \times 1 \times 1 \times 150 = 125 \text{ lb/ft}$$

Effective Width

$$E = .6S + 2.5$$

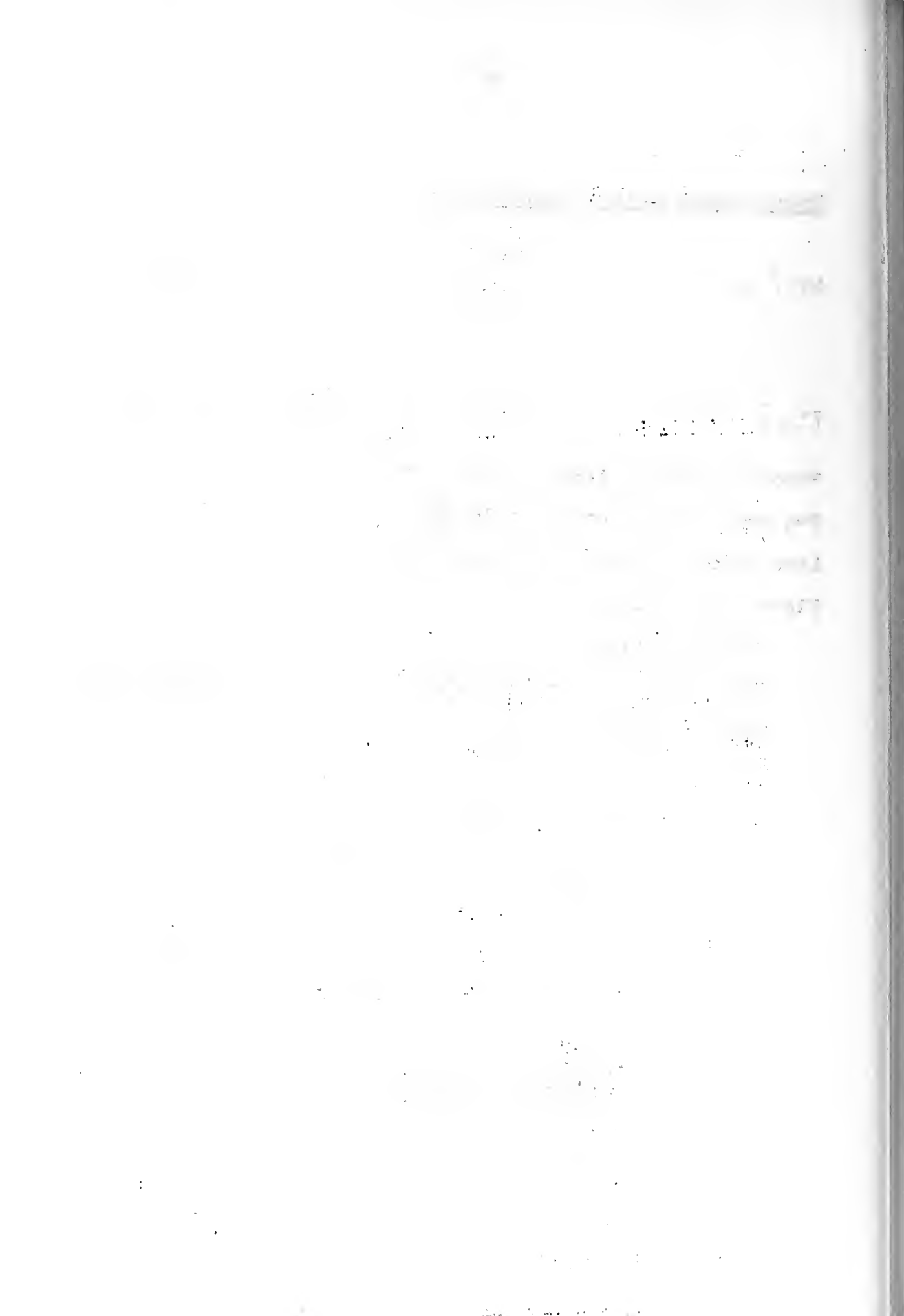
AASHO 3.3.2

$$E = .6 \times 6.167 + 2.5 = 3.7 + 2.5 = 6.2$$

Bending Moments

$$\text{Impact} = \frac{50}{L + 125} = \frac{50}{6.167 + 125} = 38\% \quad \text{AASHO 3.2.12}$$

Max. I = 30%  $\therefore$  Use 30%





## Moments:

## Edge Strip

$$\text{Pos. D.L.} = \frac{.125(6.167)^2}{14} = 0.34 \text{ ftK}$$

$$\text{L.L.} = .25 \times \frac{12}{6.2} \times 6.167 = 2.99 \text{ ftK}$$

$$\text{Impact} = .3 \times 2.99 = \underline{0.90 \text{ ftK}}$$

$$\text{Total} = 4.23 \text{ ftK}$$

## Edge Strip

$$\text{Neg. D.L.} = \frac{.125(6.167)^2}{10} = 0.48 \text{ ftK}$$

$$\text{L.L.} = .2 \times \frac{12}{6.2} \times 6.167 = 2.39 \text{ ftK}$$

$$\text{Impact} = .3 \times 2.39 = \underline{0.72 \text{ ftK}}$$

$$\text{Total} = 3.59 \text{ ftK}$$

## Intermediate Strip

$$\text{Pos. D.L.} = \frac{.1125(6.167)^2}{16} = 0.30 \text{ ftK}$$

$$\text{L.L.} = .2 \times \frac{12}{6.2} \times 6.167 = 2.39 \text{ ftK}$$

$$\text{Impact} = .3 \times 2.39 = \underline{0.72 \text{ ftK}}$$

$$\text{Total} = 3.41 \text{ ftK}$$

$$\text{Neg. D.L.} = \frac{.1125(6.167)^2}{12} = 0.40 \text{ ftK}$$

$$\text{L.L.} = .2 \times \frac{12}{6.2} \times 6.167 = 2.39 \text{ ftK}$$

$$\text{Impact} = .3 \times 2.39 = \underline{0.72 \text{ ftK}}$$

$$\text{Total} = 3.51 \text{ ftK}$$

$$\therefore \text{Design Moment} = 4.23 \text{ ftK}$$

$$f'_c = 3,000 \text{ psi}$$

AASHTO 3.4.12

$$f_s = 20,000 \text{ psi}$$

10/10/2024

10/10/2024

$$\text{NOT } x, y = \frac{S(x, y)}{S} = \dots$$

$$\text{NOT } x, y = S(x, y) \times \frac{S}{S} = \dots$$

$$\text{NOT } x, y = \dots$$

$$\text{NOT } x, y = \dots$$

10/10/2024

$$\text{NOT } x, y = \frac{S(x, y)}{S} = \dots$$

$$\text{NOT } x, y = S(x, y) \times \frac{S}{S} = \dots$$

$$\text{NOT } x, y = \dots$$

$$\text{NOT } x, y = \dots$$

10/10/2024

$$\text{NOT } x, y = \frac{S(x, y)}{S} = \dots$$

$$\text{NOT } x, y = S(x, y) \times \frac{S}{S} = \dots$$

$$\text{NOT } x, y = \dots$$

$$\text{NOT } x, y = \dots$$

$$\text{NOT } x, y = \dots$$

$$\text{NOT } x, y = \dots$$

$$\text{NOT } x, y = \dots$$

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10/10/2024

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$$n = 10$$

$$f_c = 1/3 f'_c = 1000 \text{ psi} = 1 \text{ Ksi}$$

$$r = \frac{f_s}{f_c} = 20$$

$$k = \frac{n}{n+r} = \frac{10}{30} = .333$$

$$j = 1 - \frac{k}{3} = 1 - .111 = .889$$

$$b = 12"$$

$$M = 1/2 f_c j k b d^2$$

$$d^2 = \frac{4.23 \times 2 \times 12}{1 \times .889 \times .333 \times 12} = 28.4$$

$$d = 5.32" \text{ Use } 5\frac{1}{2}"$$

$$t = 5\frac{1}{2} + 1\frac{1}{2} = 7" \text{ Assumed } 7" \text{ OK.}$$

No bond or shear checks required.

AASHTO 3.3.2(d)

Reinforcement:

$$\text{Pos. } A_s = \frac{M}{f_s j d} = \frac{4.23 \times 12}{20 \times .881 \times 5.25} = .55 \text{ in.}^2$$

$$\text{Neg. } A_s = \frac{3.59 \times 12}{20 \times .881 \times 5.25} = .465 \text{ in.}^2$$

$$+A_s \text{ use } \frac{5}{8} \phi @ 12" \text{ (straight)}$$

$$\frac{5}{8} \phi @ 12" \text{ (bend up at stringers)}$$

$$- A_s \text{ use } \frac{1}{2} \phi @ 12"$$

Distribution steel

$$\% = \frac{100}{\sqrt{s}} = \frac{100}{\sqrt{6.167}} = 40.2\%$$

$$.402(+A_s) = .402 \times .55 = .222 \text{ in.}^2$$

$$\text{Use } \frac{1}{2} \square @ 12"$$

$$2x = 2$$

$$\log(1 + 2 \cdot 10^2) = \log(201) = 2$$

$$2 = \frac{2}{1} = 2$$

$$\log(1 + \frac{2}{1}) = \log(2) = 0$$

$$\log(1 + \frac{2}{1}) = \log(2) = 0$$

$$2 = 2$$

$$\log(1 + 2 \cdot 10^2) = 2$$

$$\log(1 + \frac{2 \cdot 10^2}{1 + 2 \cdot 10^2}) = \log(2) = 0$$

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## Quantities:

## Concrete:

$$19 \times \frac{10}{12} \times 69 \times \frac{1}{27} + \frac{20}{12} \times \frac{17}{12} \times 69 \times \frac{1}{27} = 46.53 \text{ cu.yd}$$

## Steel:

$$1/2" - 1380 \text{ ft} = 1155 \text{ lb}$$

$$5/8" \phi - 2818 \text{ ft} = 2940 \text{ lb}$$

$$1/2" \phi - 1380 \text{ ft} = \frac{922 \text{ lb}}{5017 \text{ lb}}$$

## Stringer Design:

Main span - 28.83'

Dead load moment:

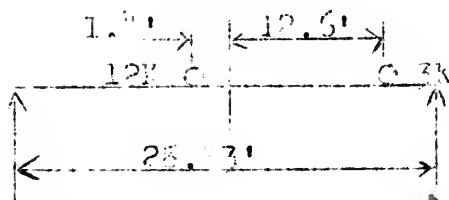
$$\text{DLM concrete slab} = \frac{6.167 \times \frac{10}{12} \times 150(28.83)^2}{8} = 80 \text{ ftK}$$

Assume stringer weight = 82 ppf

$$\text{DLM stringer} = \frac{.082(28.83)^2}{8} = 8.5 \text{ ftK}$$

$$\text{Total} = 88.5 \text{ ftK}$$

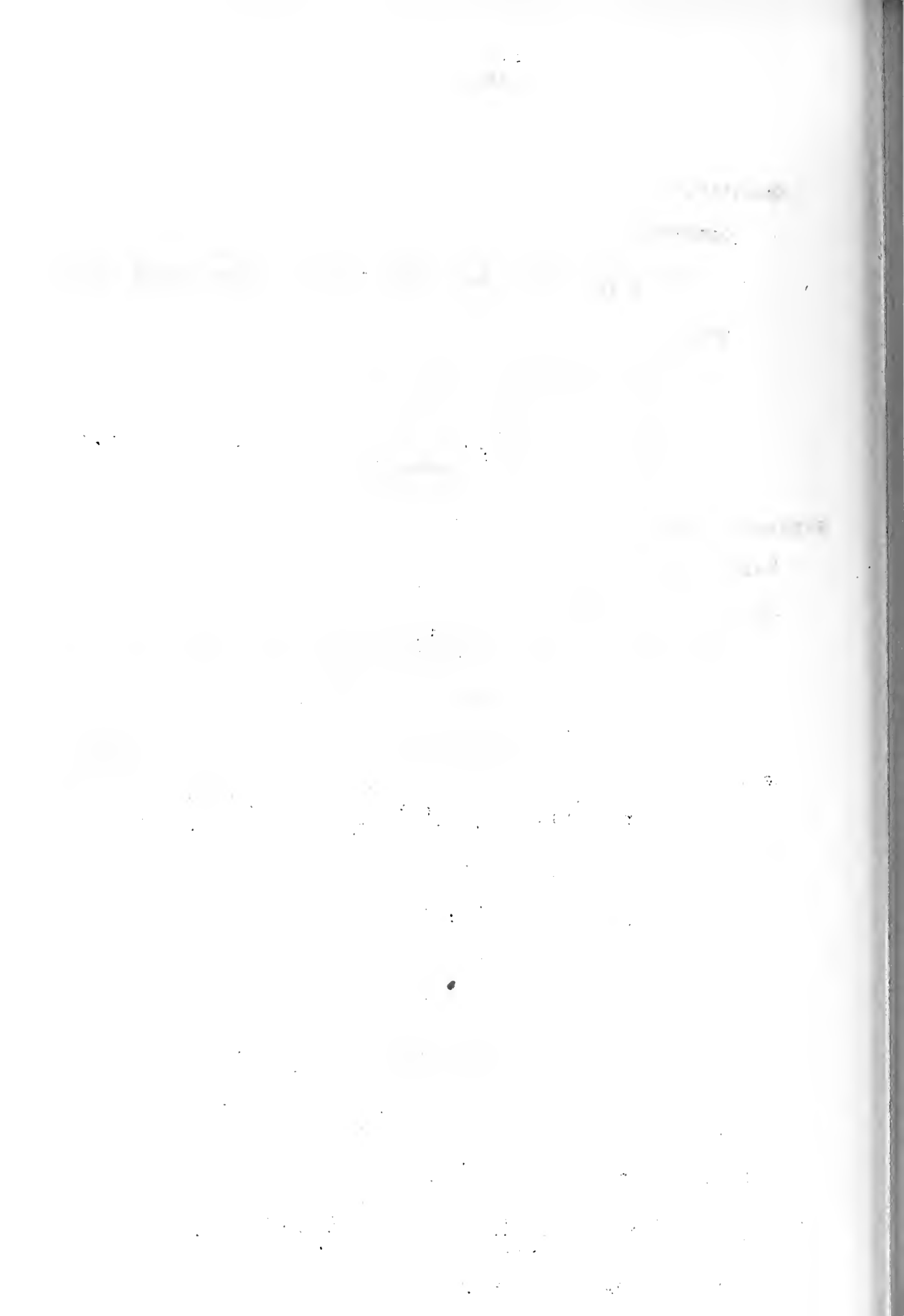
Position for max. L.L. moment



$$\text{CG load from front wheel} = \frac{12 \times 14}{15} = 11.2 \text{ ft}$$

$$R_L = \frac{3 \times 1.81 + 12 \times 15.81}{28.83} = \frac{5.4 + 190}{28.83} = 6.78 \text{ K}$$

$$\text{LLM} = 6.78 \times 13 = 87.8 \text{ ftK}$$



Overload Provision:

AASHO 3.2.4

Increase live load 100%

$$LLM = 2 \times 87.8 = 175.6 \text{ ftK}$$

Impact:

$$\% = \frac{50}{L + 125} = \frac{50}{28.83 + 125} = 32.5\%$$

Maximum % = 30  $\therefore$  Use 30%

AASHO 3.2.12

$$I = .3 \times LLM$$

Total Moment:

Normal load

$$LLM = 87.8 \text{ ftK}$$

$$\text{Impact} = 26.3 \text{ ftK}$$

$$DLM = \underline{88.5 \text{ ftK}}$$

$$\text{Total} = 202.6 \text{ ftK}$$

Overload

$$LLM = 175.6 \text{ ftK}$$

$$\text{Impact} = 52.6 \text{ ftK}$$

$$DLM = \underline{88.5 \text{ ftK}}$$

$$\text{Total} = 316.7 \text{ ftK}$$

$$\frac{\text{Overload}}{\text{Normal load}} = \frac{316.7}{202.6} = 1.545$$

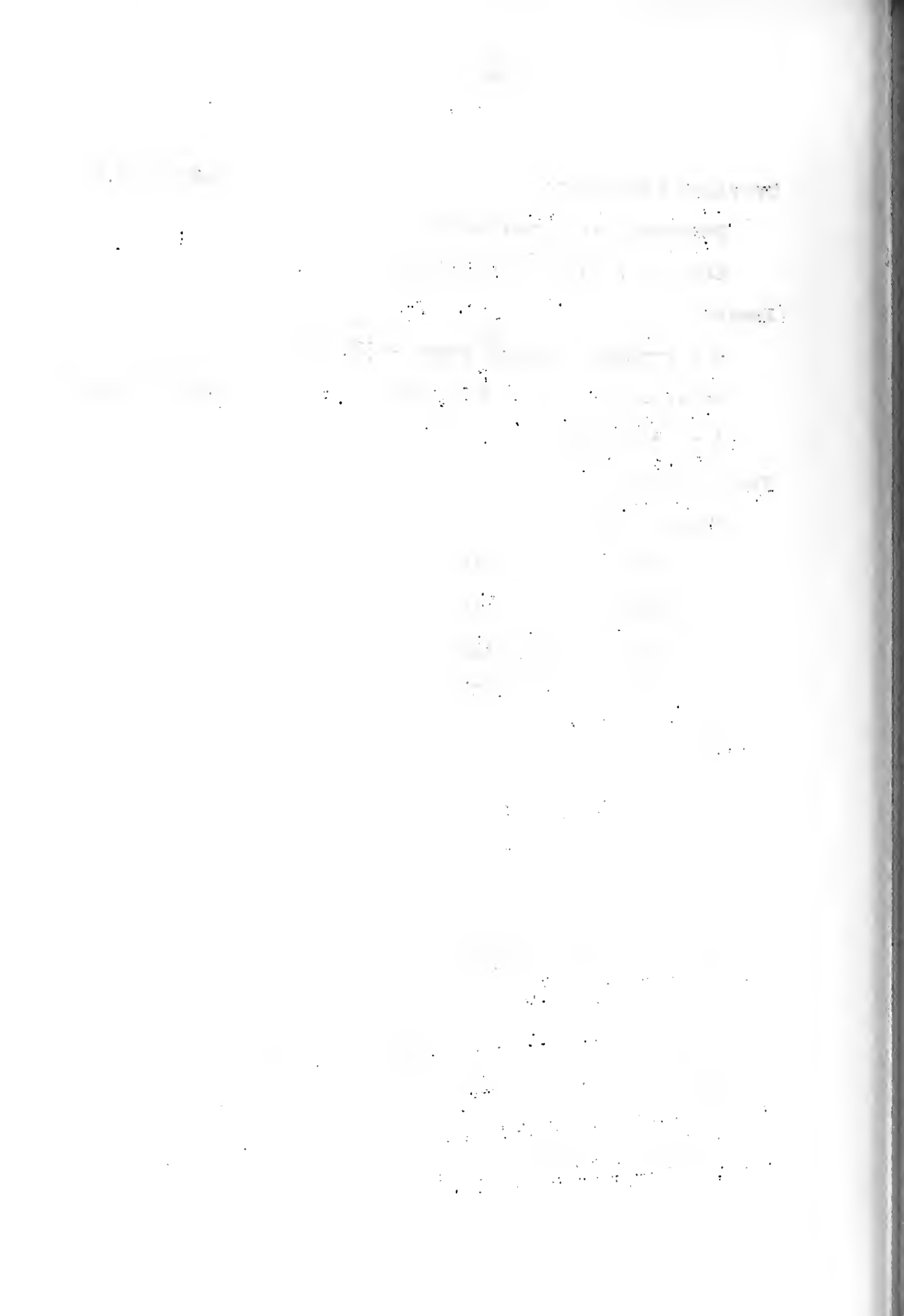
1.545 > 1.5  $\therefore$  Overload rules.

$$\text{Total design moment} = \frac{316.7}{1.5} = 211 \text{ ftK}$$

$$f (\text{allowable}) = 18 \text{ Ksi} \quad (L = 0)$$

AASHO 3.4.2

$$S = \frac{M}{f} = \frac{211 \times 12}{18} = 141 \text{ in.}^3$$





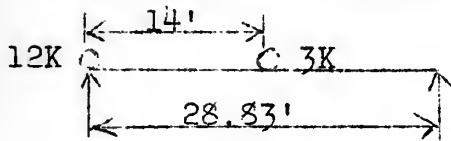
Assume 21 WF 73,  $S = 150.7 \text{ in.}^3$

$$\text{Depth to length ratio} = \frac{21}{28.83 \times 12} = .0607$$

$$.0607 > \frac{1}{25} \therefore \text{OK}$$

AASHTO 3.6.11

Maximum Reaction:



$$LLR_L = 12 + \frac{14.83}{28.83} \times 3 = 13.54 \text{ K}$$

$$DLR_L = .073 \times 14.41 + .77 \times 14.41 = 12.15 \text{ K}$$

$$\text{Impact } R_L = .3 \times 13.54 = \underline{4.07 \text{ K}}$$

$$\text{Total} = 29.76 \text{ K}$$

Shear on Web:

$$\text{Actual} = \frac{29.76}{21.24 \times .455} = 3.07 \text{ Ksi}$$

$$3.07 < 11 \therefore \text{OK}$$

Stiffeners:

$$\frac{d}{t} = \frac{21.24}{.455} = 46.8$$

AASHTO 3.6.80

$$46.8 < 60 \therefore \text{OK Stiffeners not required.}$$

The stringers for the two 20 ft. spans were designed as above. The design resulted in four 21 WF 62 stringers per span.



ALTERNATE DESIGN

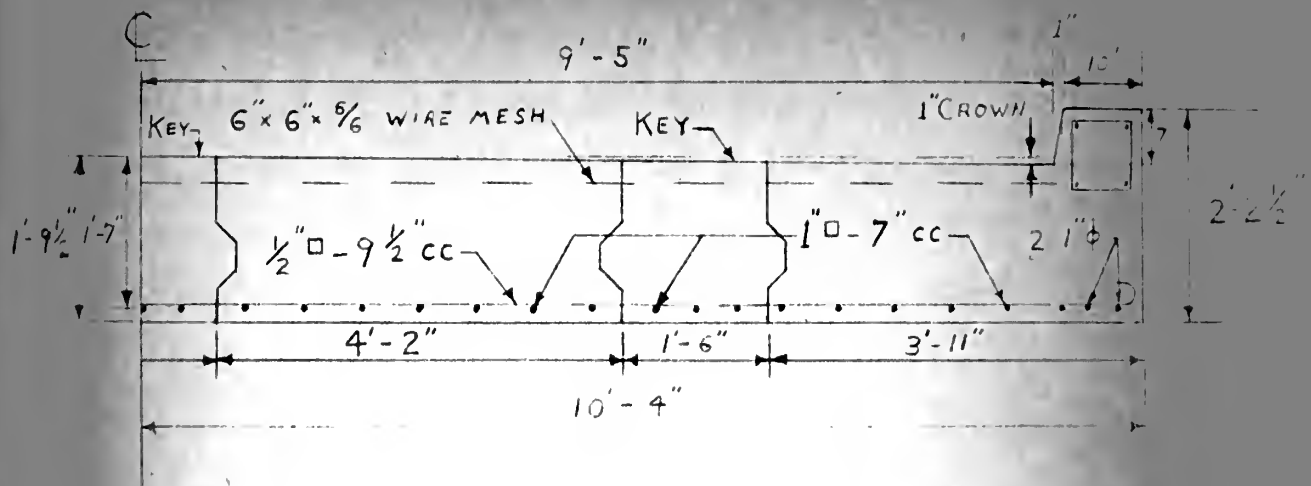
Another possible solution to the conventional design is to use a flat slab without stringers. This solution was suggested by personnel of the Bridges, Grade Separations and Structures Section, Construction Division, New York Department of Public Works.

This design was made and the two slab sections on the following page detailed. However, further correspondence with Mr. Rodgers, County Engineer of Madison County, revealed that there was no crane in the immediate locality of sufficient size to place the sections. As it would not be economical to transport such a crane for any considerable distance, a cost estimate for this design was not made.

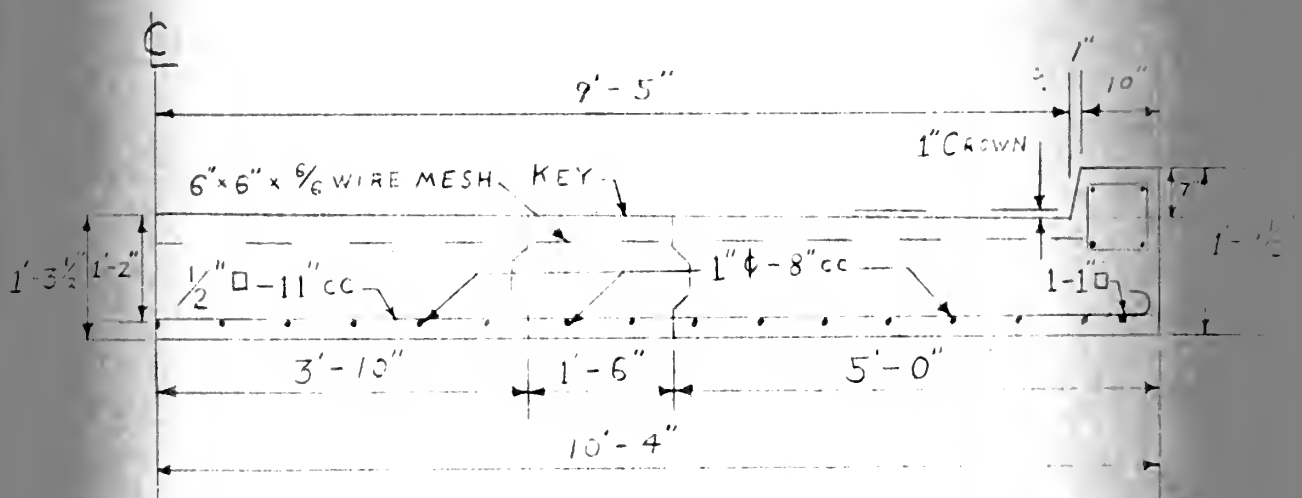
The proposed construction procedure was to pour the slab sections either in the contractor's yard or adjacent to the bridge site. When at the site they would be placed on the bents by the crane. The keys would then be cast in place, the form work being supported by bolts cast into the slab sections.

[illegible]

# CONVENTIONAL SLAB BRIDGE DETAILS ALTERNATE DESIGN



HALF CROSS SECTION - CENTER SPAN



HALF CROSS SECTION - SIDE SPAN



PRESTRESSED BRIDGE COST

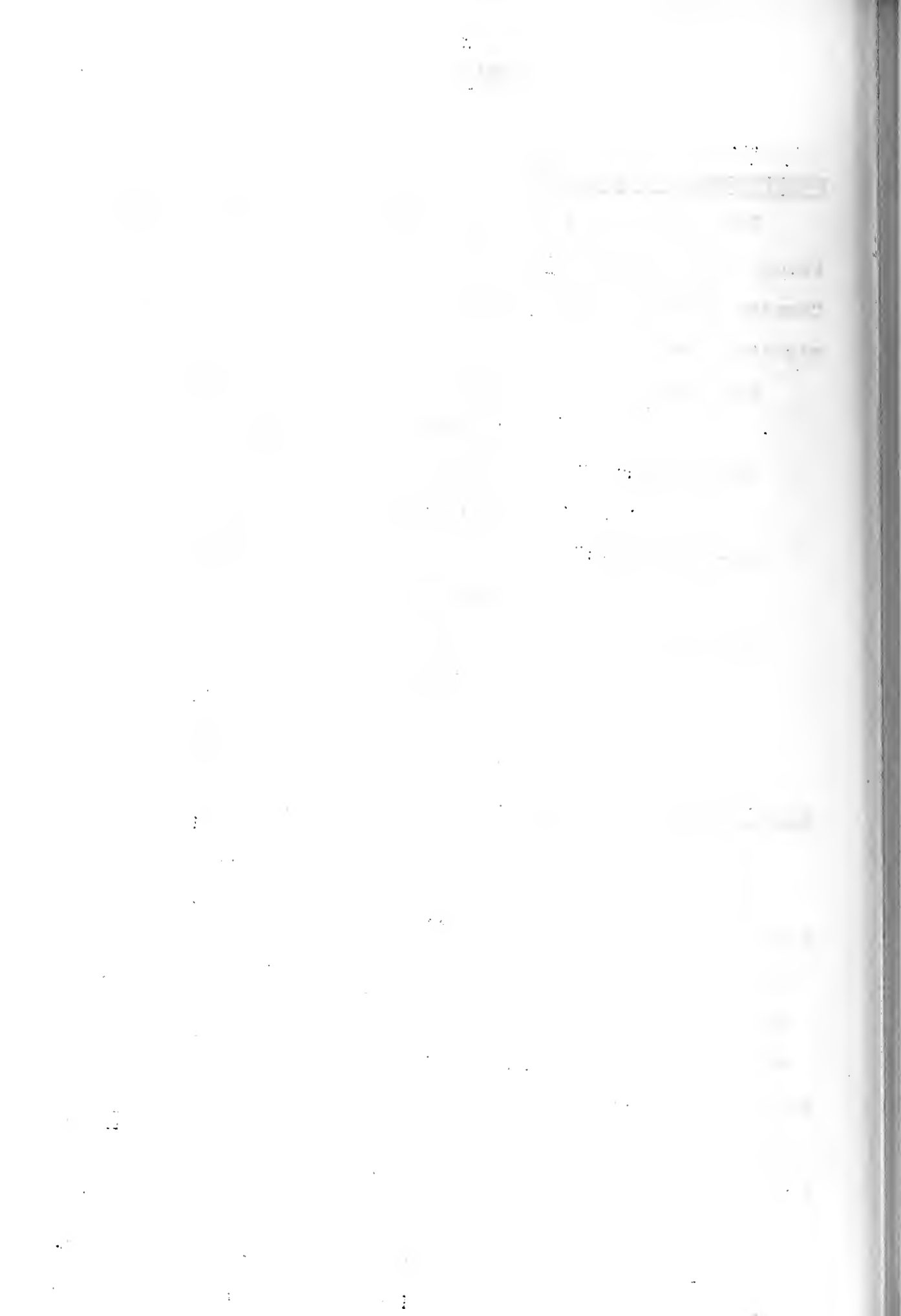
The following breakdown of costs for the prestressed bridge was supplied by the Highway Department of Madison County, Tennessee (10). These costs are for the superstructure only.

Beam Construction:	Labor	\$ 429.22
	Materials	1,809.42
Beam Laying:	Labor	234.28
	Equipment	129.01
Forming Deck:	Labor	323.78
	Equipment	36.13
Deck Concrete:	Labor	297.17
	Materials	770.27
	Equipment	<u>24.50</u>
		\$4,053.78

CONVENTIONAL BRIDGE COST (For superstructure only)

## I. Estimate of Quantities:

<u>Item</u>	<u>Unit</u>	<u>Net</u>	<u>Round</u>
Concrete	Cu yd	46.53	50
Cement	Bbl	61.3	63.0
Gravel	Ton	43.4	45.0
Sand	Ton	32.75	34.0
Structural Steel	Lb	18680	19,000
Reinforcing Steel	Lb	5017	5,500
Forms	BF	3940	4,000





## I. Estimate of Quantities (Cont'd.):

<u>Item</u>	<u>Unit</u>	<u>Net</u>	<u>Round</u>
Labor (as taken from Ref. 12):			
Mix and place concrete @ 4 hrs/cu yd	Hr	186.12	200
Place reinforcing @ 16 hrs/ton	Hr	40.1	44
Make up forms @ 6 hrs/100 SFCS	Hr	85.8	90
Erect and remove forms @ 9 hrs/100 SFCS	Hr	129	135
Move forms @ 2 hrs/100 SFCS	Hr	28.6	30

## II. Estimate of Costs:

<u>Item</u>	<u>Unit</u>	<u>Quantity</u>	<u>Unit Price</u>	<u>Cost</u>
Cement	Bbl	63	\$3.00	\$ 189.00
Gravel	Ton	45	2.24	101.00
Sand	Ton	34	1.84	62.50
In place Structural Steel	Lb	19,000	.10	1,900.00
Reinforcing Steel	Lb	5,500	.063	346.00
Bend Reinforcing	Lb	5,500	.0075	41.30
Place Reinforcing	Hr	44	1.05	46.20
Forms	BF	4,000	.09	360.00
Make up Forms	Hr	90	1.05	94.50
Erect and Remove Forms	Hr	135	1.05	142.00
Move Forms	Hr	30	.75	22.50
Mix and Place Concrete	Hr	200	.75	<u>150.00</u>
			Total	\$3,455.00
			17% Overhead	<u>586.00</u>
				\$4,041.00

I. Statement of Expenses (Continued)

Item	Amount	Total
Travel and transportation	100.00	
Postage and telegrams	25.00	
Telephone	10.00	
Gas and oil	15.00	
Repairs and maintenance	10.00	
Supplies	10.00	
Insurance	10.00	
Interest	10.00	
Other	10.00	
<b>Total</b>	<b>190.00</b>	<b>190.00</b>

II. Statement of Income

Item	Amount	Total
Salaries	100.00	
Wages	25.00	
Profits	10.00	
Interest	15.00	
Dividends	10.00	
Other	10.00	
<b>Total</b>	<b>170.00</b>	<b>170.00</b>

The preceding unit prices were taken from references 9, 11, 12 and 13.

### CONCLUSIONS

The costs of the prestressed bridge and the conventional bridge are for all practical purposes the same. This indicates that prestressed construction has certain inherent advantages, such that when it is integrated in a structure as a whole, it compares much more favorably than when individual elements are compared, as is shown in Part I.

There results a considerable saving in steel by using the prestressed design which, as brought out in the Introduction, is of ever increasing importance. This saving in steel is not achieved at the expense of using additional concrete.

Another factor which deserves consideration is the time required for construction. The prestressed beams were fabricated while the substructure was being built and were erected as soon as it was completed. The total construction time for the prestressed bridge was 7 days, which is less time than would be required to erect the conventional bridge.

Since the superstructures only were compared, it is possible that a more expensive substructure would be necessary

[illegible]

to carry the additional dead weight of the conventional bridge. If such was the case, the prestressed design would be even more favorable.

to carry the design and construction of the conventional  
bridge. It is not to be used for the design of  
beams or girders.

## PART III

## COMPARISON OF A HIGHWAY OVERPASS BRIDGE

It was next decided by the authors that the comparison should also include a large structure which was typical of those being constructed in considerable numbers at the present time. The super highway building programs which are being constantly increased in scope supplied a good example of such a structure. The Bridges, Grade Separations and Structures Section of the Construction Division, New York Department of Public Works, suggested a bridge which is part of the New York Thruway. This bridge is located east of Buffalo, New York, in Erie County.

This cost comparison is limited to the superstructure, assuming the same substructure will be used for both bridges. However, it is possible that a minor modification of the substructure may be necessary to carry an increase in superstructure dead weight.

The conventional bridge is now being constructed, under contract, by the Department. It is a four span, six lane overpass carrying Walden Avenue over the Thruway. The superstructure consists of wide flange sections with alpha spirals bonded into a conventional reinforced concrete structural

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slab. The two center spans are 66', the two side spans 44', and the total width is 91' 4" out to out, including two 3' 8" sidewalks.

The prestressed bridge was designed for this site based on the same loading and the same overall dimensions. It consists of Tee beams on four simple spans replacing the wide flange sections, alpha spirals and the structural slab. The Tee sections are the obvious choice for a simple beam because they have a large compressive area of concrete. The thin web has sufficient area to carry the compressive prestressing force when the strand is tensioned, and is also large enough to carry the strand and provide sufficient cover to protect it from the weather. By placing the top flanges side by side the waterproofing and wearing course can be placed and poured without any in-place formwork except at the sides adjacent to the sidewalks.

The proposed construction procedure is first to prepare a flat working surface adjacent to the site, then to erect plywood forms while the substructure is being constructed. The beams would then be poured and when the concrete attains sufficient strength, the forms will be stripped and used for additional beam pourings while the curing process continues. When the beams have attained sufficient additional strength, the strand will be tensioned to the design tension by means



of a hydraulic jacking unit. After this tensioning they can be handled by a crane. In handling, two precautions must be followed: 1. They must be picked up at or very close to the ends with only two points of support, and 2. they must not be allowed to tip over to any appreciable extent while being supported at the ends. This can be very easily insured by using a lifting frame and slings with hooks at the ends.

The crane will pick up the beams and place them on the bents in the same manner as is done in erecting steel beams. When all the beams in one span are erected, the transverse strands will be threaded through the holes cast for them, in both the top and bottom of the transverse ribs, and then tensioned by means of the same hydraulic jacking unit and procedure. These ribs and strands will form transverse beams capable of resisting either positive or negative moment because of the dual strand position. These beams serve to tie the beams together rigidly and also distribute any concentrated load to the entire width of the bridge. The prestressed superstructure at this stage is equivalent to the conventional superstructure after the structural slab has been poured, allowed to cure, and the form work removed. The remaining work to complete the bridge would be done in almost exactly the same manner and sequence for both superstructures



As was previously stated, the authors sought to limit the comparison as much as possible in order to bring into sharp contrast the two designs and the cost of constructing each. This was aided by comparing only the main longitudinal structural system of the superstructure, assuming that the lengths of span and other limiting conditions of design were determined by considerations other than structural economy.

The authors recognize that there are many other solutions to the basic problem, such as eliminating the intermediate bents and using two spans of 110 feet each. This span length is not excessive for prestressed construction. This is because the stresses induced by flexure due to dead load alone are entirely eliminated at the time of prestressing so as to have no effect on the total load the beam can carry. This is not true of vertical shear or diagonal tension at the ends but this is no problem in prestressed beams (6). However, a comparison based on this solution or the many others possible could not be done due to time limitations. A study of the most economical combination of substructure and superstructure for any bridge is an involved and time consuming job, requiring complete and detailed information on foundation conditions, superstructure and substructure costs, which were not available to the authors.



### PRESTRESSED BEAM DESIGN

The design of the prestressed beams was done using a Tee section. Since there is no direct solution for an irregular section, such as Mr. Uziel's for rectangular sections (5), it was a trial and error procedure using  $\frac{P}{A} \pm \frac{MC}{I}$ .

In section I of the design the loads were computed, the number of beams in the bridge assumed, and the bending moment due to live load and wearing course calculated.

In section II the required section moduli were calculated and a section assumed and checked. In section III the dead load moment was calculated. The prestressing force and eccentricity required to give the favorable stress condition desired were calculated in section IV. This permitted the calculation of the required strand size in section V and the selection of a strand from the Strand Physical Properties Table, page 24. With the size of section and strand determined, the stresses in the top and bottom fibers at the center line were checked in section VI under these two critical conditions: 1. when the strand is tensioned and the dead load of the beam alone is acting, and 2. when the beam is carrying the full dead and live design loads. The major principal tensile stress on the neutral axis at the support

THEORY OF THE EARTH

The theory of the earth is a branch of geology which deals with the origin and development of the earth and its various parts. It is a science which seeks to explain the causes and effects of the various geological phenomena which we observe in nature.

$$\frac{1}{2} = \frac{1}{2}$$

In the theory of the earth, we find that the earth is a sphere, and that it is composed of various layers or strata. These strata are formed by the deposition of various materials, and they are arranged in a regular order, which is called the geological column.

The theory of the earth is a science which seeks to explain the causes and effects of the various geological phenomena which we observe in nature. It is a science which seeks to explain the causes and effects of the various geological phenomena which we observe in nature.

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was then calculated as a measure of diagonal tension in section VII. The transverse steel was designed in accordance with AASHTO 3.3.2(c). The final calculation was made for the required area of the bearing plates at the ends of the strands in section IX.

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the fourth is the  
the fifth is the

DESIGN OF CENTER SPANS USING TEE BEAM SECTIONS

## I. Loads

6 Lanes of H20-44

Span = 66'-0"; Lane width = 13'-4"

Sidewalk = 2'-6"; Mall = 4'-0"

From AASHO Specifications,

$$M_L \text{ per lane} = 645,000 \text{ ft.lb.} = 7,740,000 \text{ in.lb.}$$

$$\text{Impact} = \frac{50}{L + 125} = \frac{50}{66 + 125} = .262$$

$$M_L + \text{Impact} = 1.262 \times 7,740,000 = 9,750,000 \text{ in.lb.}$$

Assume 42 sections per span, 3 sections under sidewalk, 39 sections under road

$$\text{width of section} = \frac{91.33 \times 12}{42} = 26\frac{1}{8}"$$

$$M_L \text{ per section} = \frac{6 \times 9,750,000}{39} = 1,500,000 \text{ in.lb.}$$

Assume 4" wearing course

$$w_s = \frac{26.125 \times 4 \times 144}{144} = 104.5 \text{ ppf}$$

$$M_s = \frac{104.5(66)^2 \times 12}{8} = 683,000 \text{ in.lb.}$$

$$M_T = M_L + M_s = 1,500,000 + 683,000 = 2,183,000 \text{ in.lb.}$$

## II. Section Modulus Required

$$f'_c = 5000 \text{ psi}$$

$$f_c = 2000 \text{ psi}$$

$$S = \frac{M}{f_c} = \frac{2,183,000}{2000} = 1092.5 \text{ in.}^3$$

21

1871

1872

1873

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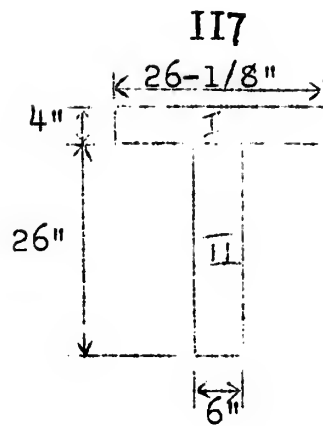
1896

1897

1898

1899

1900



Section	Size	A	y	Ay	Ay <sup>2</sup>	I <sub>o</sub>
I	4" x 26-1/8"	104.5	2	209	418	139.5
II	6" x 26"	156.0	17	2650	45,100	8,780.0
Total		260.5		2859	45,518	8,919.5

$$v_T = \frac{Ay}{A} = \frac{2859}{260.5} = 11"$$

$$y_B = 30 - 11 = 19"$$

$$I_x = I_o + Ay^2 = 8,919.5 + 45,518 = 54,437.5 \text{ in.}^4$$

$$I_{CG} = I_x - Ay_T^2 = 54,437.5 - 260.5(11)^2$$

$$I_{CG} = 54,437.5 - 31,500 = 22,937.5 \text{ in.}^4$$

$$S_T = \frac{I_{CG}}{y_T} = \frac{22,937.5}{11} = 2085 \text{ in.}^3$$

$$S_B = \frac{I_{CG}}{y_B} = \frac{22,937.5}{19} = 1205 \text{ in.}^3$$

$$2085 \text{ and } 1205 > 1092.5 \therefore \text{OK}$$

### III. Dead Load Moment

Assume 5 diaphragms in beam @ 11' cc

Diaphragms are tee sections of same cross section as beams.

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102

103

104

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120

$$w_{DL} = \frac{(26 \times 6 + 4 \times 26\frac{1}{8})}{144} \times 144 + \frac{5(6 \times 26)(26\frac{1}{8} - 6)}{66 \times 1728} \times 144$$

$$w_{DL} = 260.5 + 20.9 = 281.4 \text{ ppf}$$

$$M_{DL} = \frac{281.4(66)^2 \times 12}{8} = 1,840,000 \text{ in.lb.}$$

#### IV. Prestressing Force and Eccentricity

Critical conditions are stress in bottom fiber under dead and live loads and stress in top fiber after prestressing and prior to application of loads.

A. Stress in bottom fiber under dead and live load

$$\frac{P}{A} + \frac{Pe}{S_B} - \frac{M_{DL}}{S_B} - \frac{M_T}{S_B} = 0$$

$$\frac{P}{260.5} + \frac{Pe}{1205} - \frac{1,840,000}{1205} - \frac{2,185,000}{1205} = 0$$

B. Stress in top fiber

$$\frac{P}{A} - \frac{Pe}{S_T} + \frac{M_D}{S_T} = 0$$

$$\frac{P}{260.5} - \frac{Pe}{2085} + \frac{1,840,000}{2085} = 0$$

Solving for P,

$$A. \quad \frac{P}{260} + \frac{Pe}{1205} - \frac{4,025,000}{1205} = 0$$

$$B. \quad \frac{P}{260} - \frac{Pe}{2085} + \frac{1,840,000}{2085} = 0$$

---


$$P = 172,000$$

Substituting P in A.,

$$\frac{172,000}{260.5} + \frac{172,000e}{1205} - 3340 = 0$$

$$e = 18.8"$$





$e = 18.5"$  is too large. It would not allow sufficient cover.

Assuming 2" cover and two strands place C.G. of steel 6" from bottom of beam.

$$\therefore e = 19 - 6 = 13"$$

Revise  $P$  for  $e = 13"$  by substituting  $e = 13"$  in equation A.

$$\frac{P}{260.5} + \frac{13P}{1205} - 3340 = 0$$

$$4.61P + 13P = 4,020,000$$

$$P = \frac{4,020,000}{17.61} = 228,000 \text{ lb.}$$

#### V. Strand Size

Strand design stress = 105,000 psi

$$A_s = \frac{P}{105,000} = \frac{228,000}{105,000} = 2.17 \text{ in.}^2$$

Use 2 -  $1\frac{3}{8}"$  strands

$$A_s = 2.24 \text{ in.}^2$$

#### VI. Stress Check

A. Top and bottom fibers at center line due to dead load and initial prestress. Strands designed for 105,000 psi but initially prestressed to 125,000 psi to take into account loss of prestress due to plastic flow and creep.

$$P' = P \times \frac{125,000}{105,000} = 228,000 \times \frac{125,000}{105,000} = 272,000 \text{ lb.}$$

The first part of the paper is devoted to a discussion of the general principles of the theory of the structure of the atom. It is shown that the structure of the atom is determined by the laws of quantum mechanics, and that the structure of the atom is determined by the laws of quantum mechanics.

The second part of the paper is devoted to a discussion of the general principles of the theory of the structure of the atom. It is shown that the structure of the atom is determined by the laws of quantum mechanics, and that the structure of the atom is determined by the laws of quantum mechanics.

The third part of the paper is devoted to a discussion of the general principles of the theory of the structure of the atom. It is shown that the structure of the atom is determined by the laws of quantum mechanics, and that the structure of the atom is determined by the laws of quantum mechanics.

The fourth part of the paper is devoted to a discussion of the general principles of the theory of the structure of the atom. It is shown that the structure of the atom is determined by the laws of quantum mechanics, and that the structure of the atom is determined by the laws of quantum mechanics.

## 1. Stress in bottom fiber

$$f_b = \frac{P'}{A} + \frac{P'e}{S_b} - \frac{M_D}{S_b}$$

$$f_b = \frac{272,000}{260.5} + \frac{13 \times 272,000}{1205} - \frac{1,840,000}{1205}$$

$$f_b = 1045 + 2930 - 1530$$

$$f_b = 3975 - 1530 = 2445 \text{ psi (compression)}$$

$$f_c = 5000$$

$$f'_c = .45 \times 5000 = 2250 \text{ psi}$$

Stress in bottom fiber is 195 psi greater than  $f'_c$  but since creep plastic flow and any load will reduce it below  $f'_c$  it is considered satisfactory.

## 2. Stress in top fiber

$$f_t = \frac{P'}{A} - \frac{P'e}{S_T} + \frac{M_D}{S_T}$$

$$f_t = 1045 - \frac{272,000 \times 13}{2085} + \frac{1,840,000}{2085}$$

$$f_t = 1045 - 1700 + 885$$

$$f_t = 230 \text{ psi (compression)} \therefore \text{OK}$$

## B. Top and bottom fibers at center line due to dead and live load

## 1. Stress in bottom fiber

$$f_b = \frac{P}{A} + \frac{Pe}{S_b} - \frac{M_D}{S_b} - \frac{M_T}{S_b}$$

$$f_b = \frac{228,000}{260.5} + \frac{13 \times 228,000}{1205} - \frac{1,840,000}{1205} - \frac{2,188,000}{1205}$$



$$f_b = 875 + 2460 - 1525 - 1815$$

$$f_b \approx 0 \therefore \text{OK}$$

2. Stress in top fiber

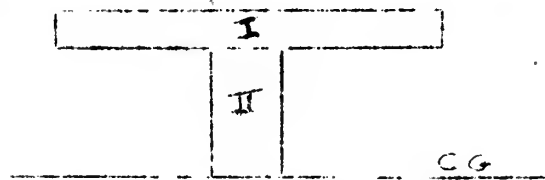
$$f_t = \frac{P}{A} - \frac{Pe}{S_t} + \frac{M_D}{S_t} + \frac{M_T}{S_t}$$

$$f_t = \frac{228,000}{260.5} - \frac{13 \times 228,000}{2085} + \frac{1,840,000}{2085} + \frac{2,188,000}{2085}$$

$$f_t = 875 - 1425 + 885 + 1055$$

$$f_t = 1390 \text{ psi (compression)} \therefore \text{OK}$$

VII. Diagonal Tension and Horizontal Shear on C.G. at Support



Section	A	y	Ay
4" x 26 $\frac{1}{8}$ "	104.5	9	940.5
7" x 6"	42	3.5	147.0

$$\text{Total} = 1087.5$$

$$\text{Horizontal Shear} = \frac{V}{I t} \times Ay$$

$$I = 22,937.5$$

$$t = 6"$$

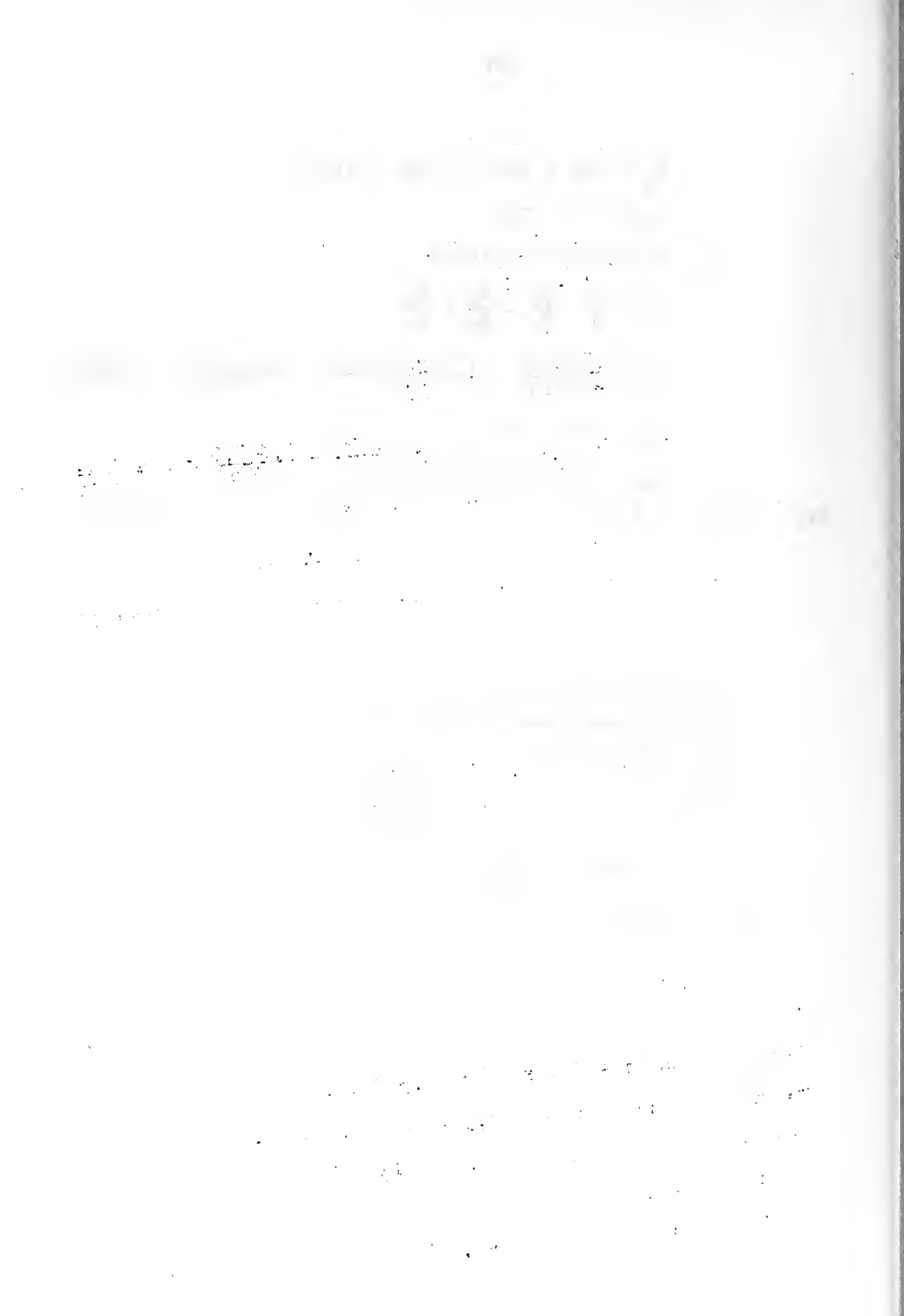
$$\text{Dead load shear} = 281 \times 66 = 18,500 \text{ lb.}$$

$$\text{Wearing Course shear} = 104.5 \times 66 = 6,900 \text{ lb.}$$

$$\text{Live load shear} = 47,100 \text{ lb. per lane (AASHO)}$$

$$\text{Impact} = .262$$

$$\text{Impact shear} = .262 \times 47,100 = 12,350 \text{ lb. per lane}$$



$$\text{Total live load shear} = \frac{6(47100 + 12350)}{39} = 9140 \text{ lb/beam}$$

$$V = 9,140 + 18,500 + 6,900 = 34,540 \text{ lb.}$$

$$\therefore s = \frac{34,540}{22,937.5 \times 6} \times 1087.5 = 273 \text{ psi}$$

$$\text{Diagonal tension } f_{DT} = \frac{f'_t}{2} + \sqrt{s^2 + \frac{f'_t}{2}^2}$$

$$f'_t = \frac{P}{A} = \frac{228,000}{260.5} = 875$$

$$f_{DT} = \frac{875}{2} + \sqrt{(273)^2 + \frac{875}{2}^2}$$

$$f_{DT} = 437.5 + \sqrt{266,000}$$

$$f_{DT} = 437.5 + 516$$

$$f_{DT} = 953.5 \text{ psi (tension)}$$

Code allows .03  $f'_c$  without stirrups

$$.03 f'_c = 150 \text{ psi}$$

$$150 > 953.5 \therefore \text{no stirrups}$$

#### VIII. Transverse Steel

AASHTO 3.3.2(c)

$$\rho = \frac{100}{\sqrt{s}} = \frac{100}{\sqrt{66}} = .13\%$$

$$42 \times .13 \times 2.11 = 11.5 \text{ in.}^2$$

$$\text{Area per diaphragm} = \frac{11.5}{5} = 2.3 \text{ in.}^2$$

Use 2 -  $1\frac{7}{16}$ " strands top and bottom

#### IX. Bearing Plate

$$P = 228,000 \text{ lbs}$$

$$\text{Area required} = \frac{P}{\text{Allowable bearing pressure}}$$

$$\text{Allowable bearing pressure} = 2200 \text{ psi}$$

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$$\frac{228,000}{2200} = 103.8 \text{ in.}^2$$

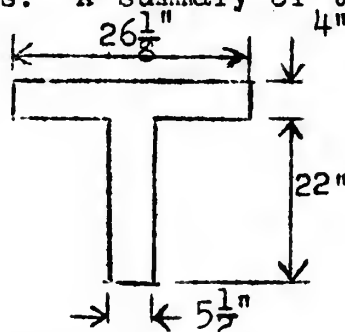
$$\text{Area of 2 - 5" diameter holes} = 39.2 \text{ in.}^2$$

$$\text{Gross area of plate} = 103.8 + 39.2 = 143 \text{ in.}^2$$

Use a plate 10" x 15".

### DESIGN OF END SPANS USING TEE SECTIONS

This design was done in the same manner as for the center span; however, the design is not included here as the authors felt it would be superfluous. A summary of the results of this design follows:



1. Cross section found to be satisfactory:

$$A = 225 \text{ in.}^2$$

$$\text{Section modulus (bottom fiber) actual} = 850 \text{ in.}^3$$

$$\text{Section modulus (bottom fiber) required} = 728 \text{ in.}^3$$

$$\text{Section modulus (top fiber) actual} = 1606 \text{ in.}^3$$

2. Prestressing force:

$$P = 120,100 \text{ lbs. Use one } 1\text{-}7/16" \text{ strand}$$

$$e = 14.25"$$

3. Stresses at centerline:

- A. Under prestressing force and dead weight of beam alone

$$\text{Bottom fiber} = + 2,078 \text{ psi compression}$$

Use a plate 10" x 12".  
 Gross area of plate =  $10 \times 12 = 120 \text{ in.}^2$   
 Area of 2 - 5" diameter holes =  $2 \times 19.6 = 39.2 \text{ in.}^2$   
 $\frac{228.000}{2200} = 103.8 \text{ in.}^2$

# DESIGN OF THE STAYS USING TWO SECTIONS

This design was done in the same manner as for the center span, however, the design is not included here as the authors felt it would be superfluous. A summary of the results of this design follows:



1. Gross section found to be satisfactory:  
 $A = 228 \text{ in.}^2$   
 Section modulus (bottom fiber) actual =  $850 \text{ in.}^3$   
 Section modulus (bottom fiber) required =  $718 \text{ in.}^3$   
 Section modulus (top fiber) actual =  $1506 \text{ in.}^3$   
 Section modulus (top fiber) required = 1506 in.<sup>3</sup>
2. Stress being found:  
 $P = 250,100 \text{ lbs.}$  and  $M = 17,150 \text{ ft.-lbs.}$   
 $f_c = 14,250$   
 Stresses at end of stay:  
 A. Due to compressive force = 17,150 ft.-lbs.  
 B. Due to bending moment = 17,150 ft.-lbs.  
 Bottom fiber =  $24,750 \text{ psi}$  and top fiber =  $24,750 \text{ psi}$

Top fiber = -166 psi tension

B. Under full dead and live design loads

Bottom fiber = +3 psi compression

Top fiber = +815 psi compression

4. Major principal tensile stress

$f_t = 58.7$  psi (tension)

Allowable tension =  $.03 f'_c = 150$  psi

5. Bearing plate area = 81 in.<sup>2</sup>

Use a plate 9" x 9".

#### SUMMARY OF QUANTITIES

The elements which are compared in the two bridges are only those elements of the conventional bridge which were replaced by the prestressed beams in the prestressed bridge. All other items such as curbs, railings, waterproofing and wearing course were considered identical in both designs and thus not subject to comparison.

I. Prestressed Bridge - main longitudinal beams

A. Concrete 726.6 cu yds

B. Steel 115,850 lbs

II. Conventional Bridge

A. Concrete for 7" structural slab 530.2 cu yds

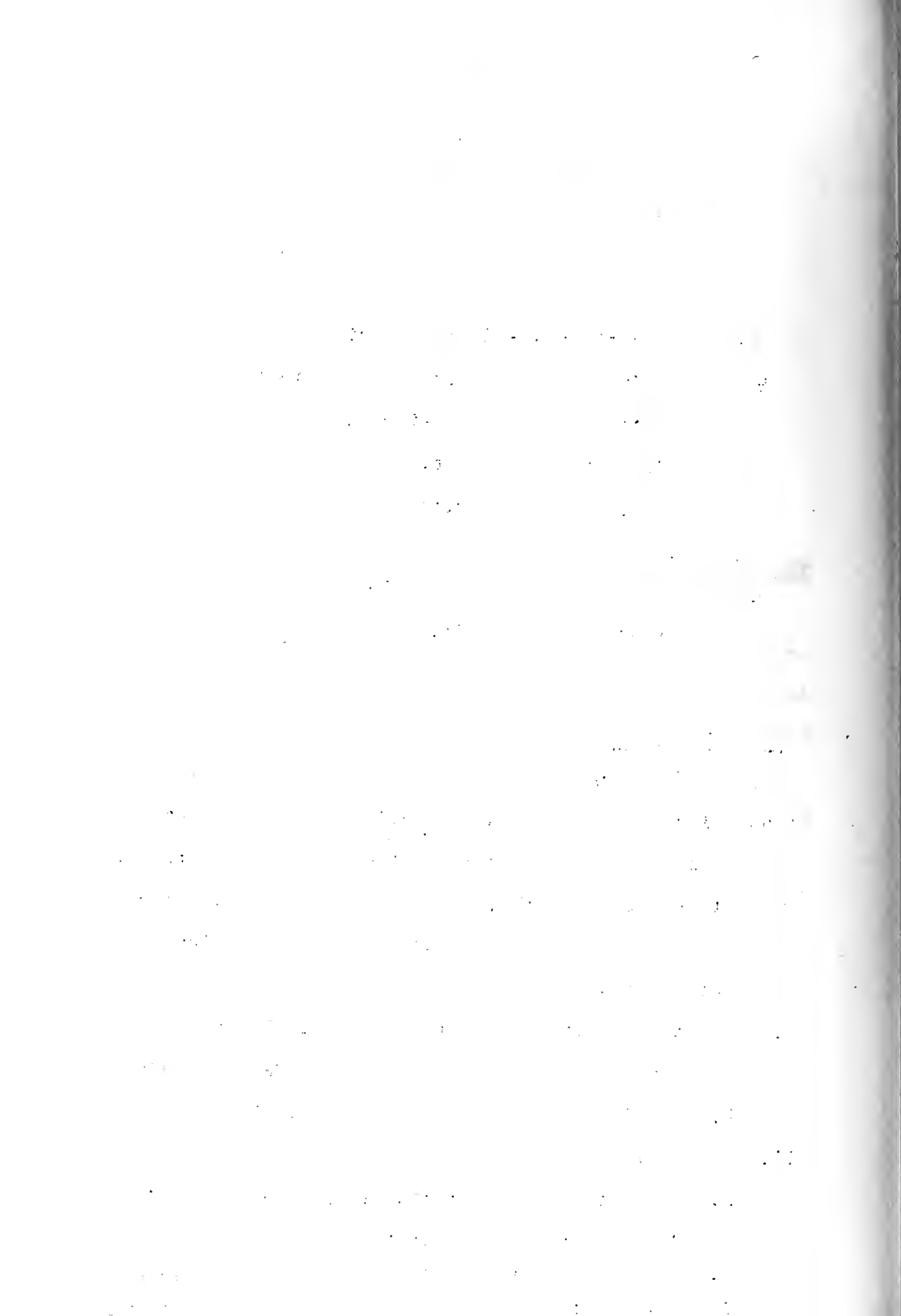
Cement for above concrete 825 Bbl

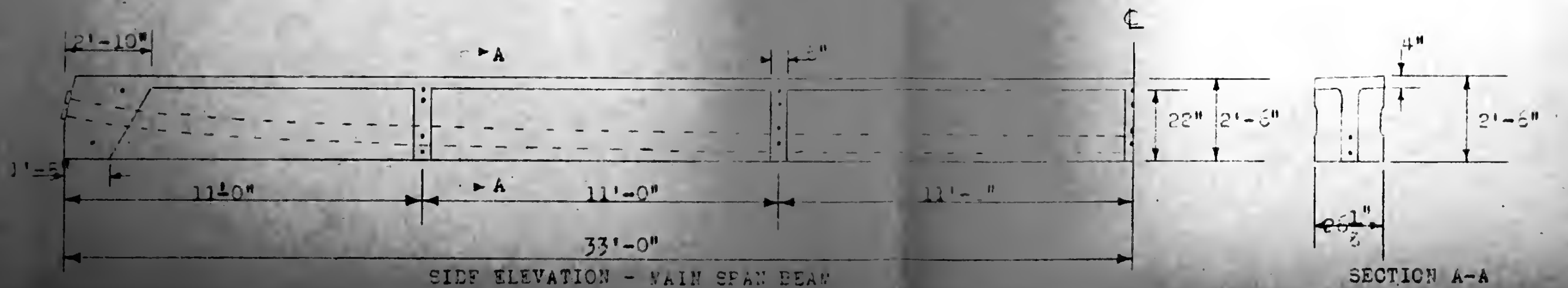
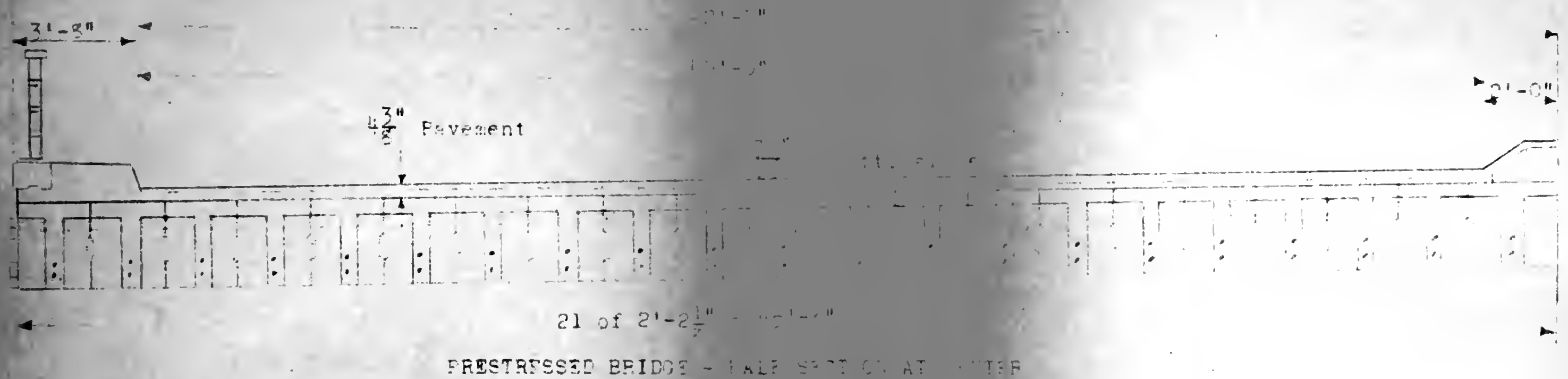
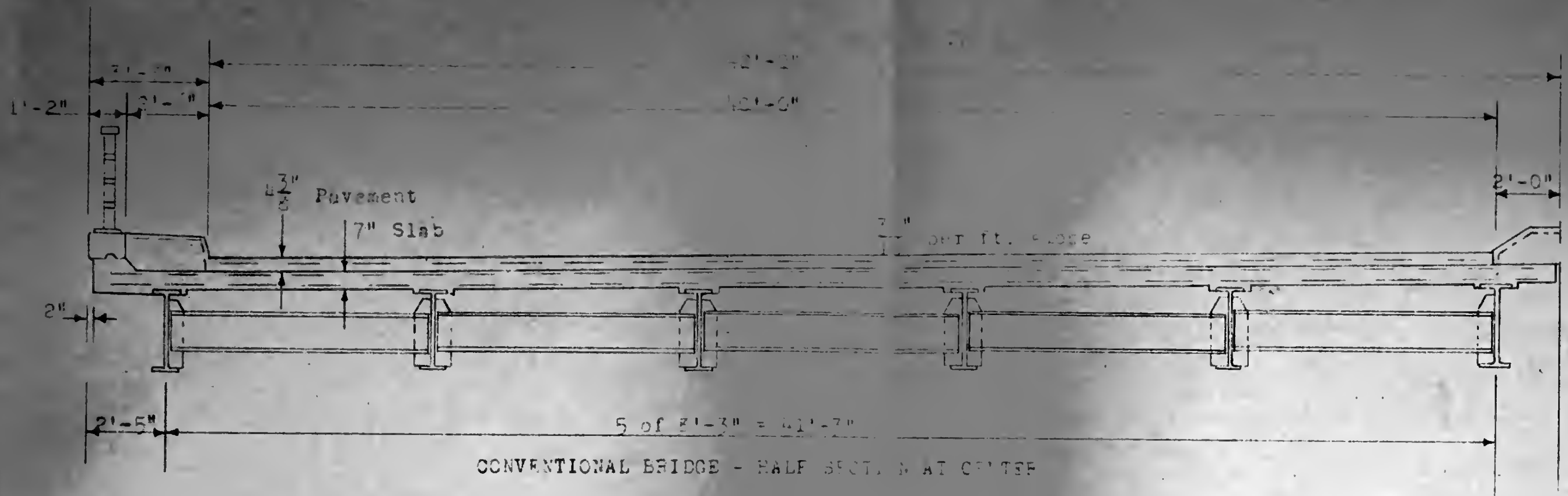
B. Slab reinforcing steel 142,082 lb

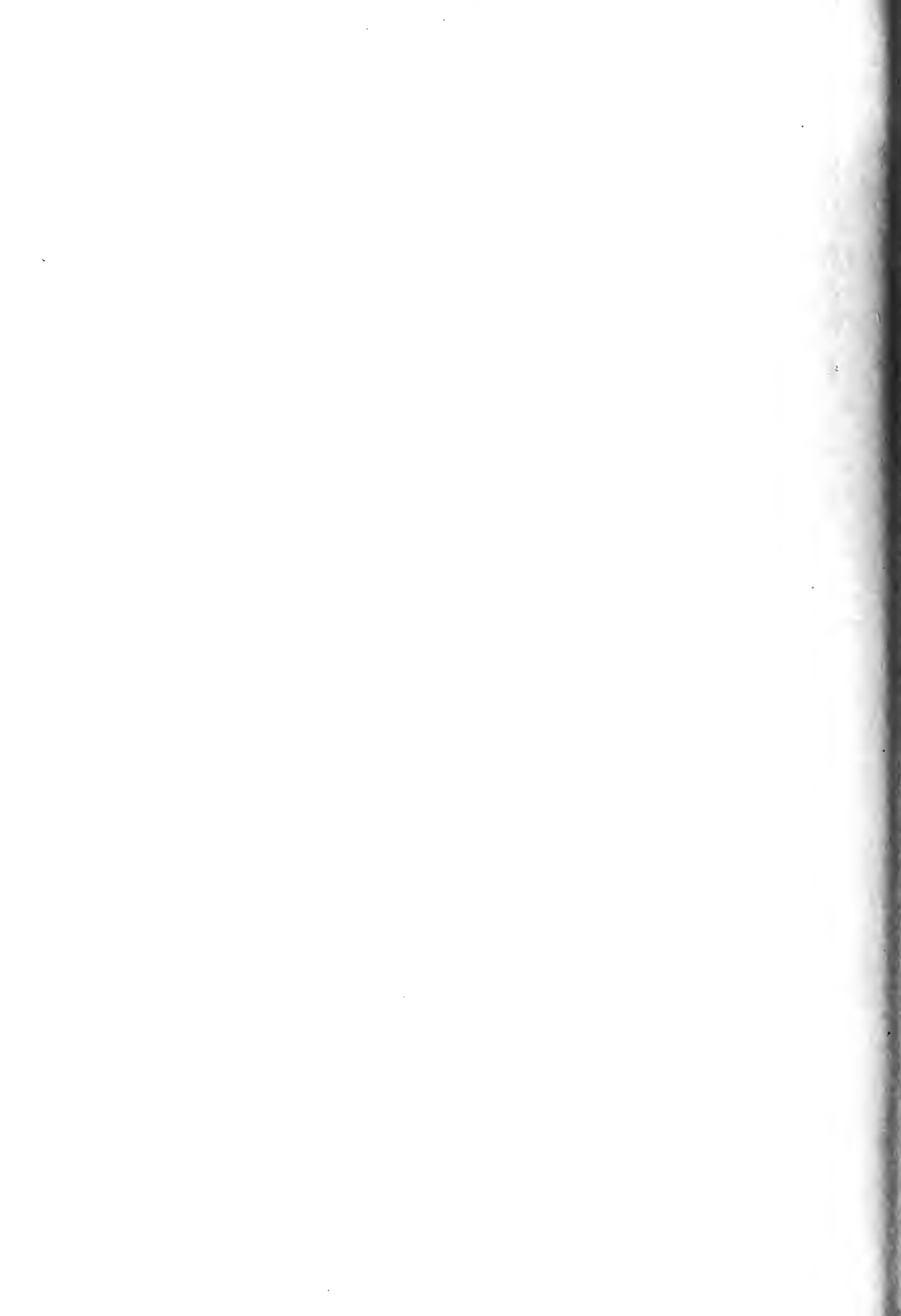
C. Spiral steel 6,370 lb

D. Structural steel 408,000 lb

Total steel 556,452 lb







ESTIMATE OF PRESTRESSED BRIDGE COSTS

The cost of the prestressed beams was estimated by the same procedure as used in Part I. The concrete price was quoted by Buffalo Gravel Corporation of Buffalo, N. Y., for delivery to the site of the bridge. The strand prices were quoted by John A. Roebling's Sons, supplier. The erection cost was estimated on the basis of erecting an equivalent weight of steel. The hourly labor rates were quoted by the Buffalo office of the American Federation of Labor. All costs are those effective on March 1, 1951.

## I. Fabrication

## A. Center Spans

Plywood forms (each form used for 5  
beam pourings), 84 beams,

528.75 SFCS/beam @ \$.0594/SFCS = \$2,632.00

Bearing assemblies (material and  
labor to fabricate), 168 pairs

@ \$3.308/pr = 556.00

Ready mix concrete, 84 beams,

5.475 cu yd/each = 460 cu yds

@ \$10.40 = 4,780.00

Carpenter labor, 84 beams,

528.75 SFCS/each = 44,400 SFCS

44,400 SFCS x  $\frac{9 \text{ hr}}{100 \text{ SFCS}}$  x  $\frac{\$2.375}{\text{hr}}$  = 9,500.00

STATE OF NEW YORK

IN SENATE,  
 January 10, 1900.  
 REPORT  
 OF THE  
 COMMISSIONERS OF THE LAND OFFICE,  
 IN ANSWER TO A RESOLUTION PASSED BY THE SENATE,  
 APRIL 18, 1899.  
 ALBANY:  
 J. B. LIPPINCOTT & CO., PRINTERS,  
 1899.



Common labor, 84 beams,

$$528.75 \text{ SFCS/each} = 44,400 \text{ SFCS}$$

$$44,400 \text{ SFCS} \times \frac{4.5 \text{ hr}}{100 \text{ SFCS}} \times \$1.775 = \$3,550.00$$

Structural iron worker labor,

$$168 \text{ strands} @ 1/2 \text{ hr/strand}$$

$$@ \$2.525/\text{hr} = 212.00$$

#### B. End Spans

Plywood forms (each form used for

$$5 \text{ beam pourings}), 84 \text{ beams,}$$

$$320 \text{ SFCS/beam} @ \$1.0594/\text{SFCS} = 1,597.00$$

Bearing assemblies (material and

$$\text{labor to fabricate})$$

$$84 \text{ pairs} @ \$3.308/\text{pr} = 278.00$$

Ready mix concrete, 84 beams,

$$3.175 \text{ cu yd/each} @ \$10.40 = 2,775.00$$

Carpenter labor, 84 beams,

$$320 \text{ SFCS/each} = 26,900 \text{ SFCS}$$

$$26,900 \text{ SFCS} \times \frac{9 \text{ hr}}{100 \text{ SFCS}} \times \frac{\$2.375}{\text{hr}} = 5,750.00$$

Common labor, 84 beams,

$$320 \text{ SFCS/each} = 26,900 \text{ SFCS}$$

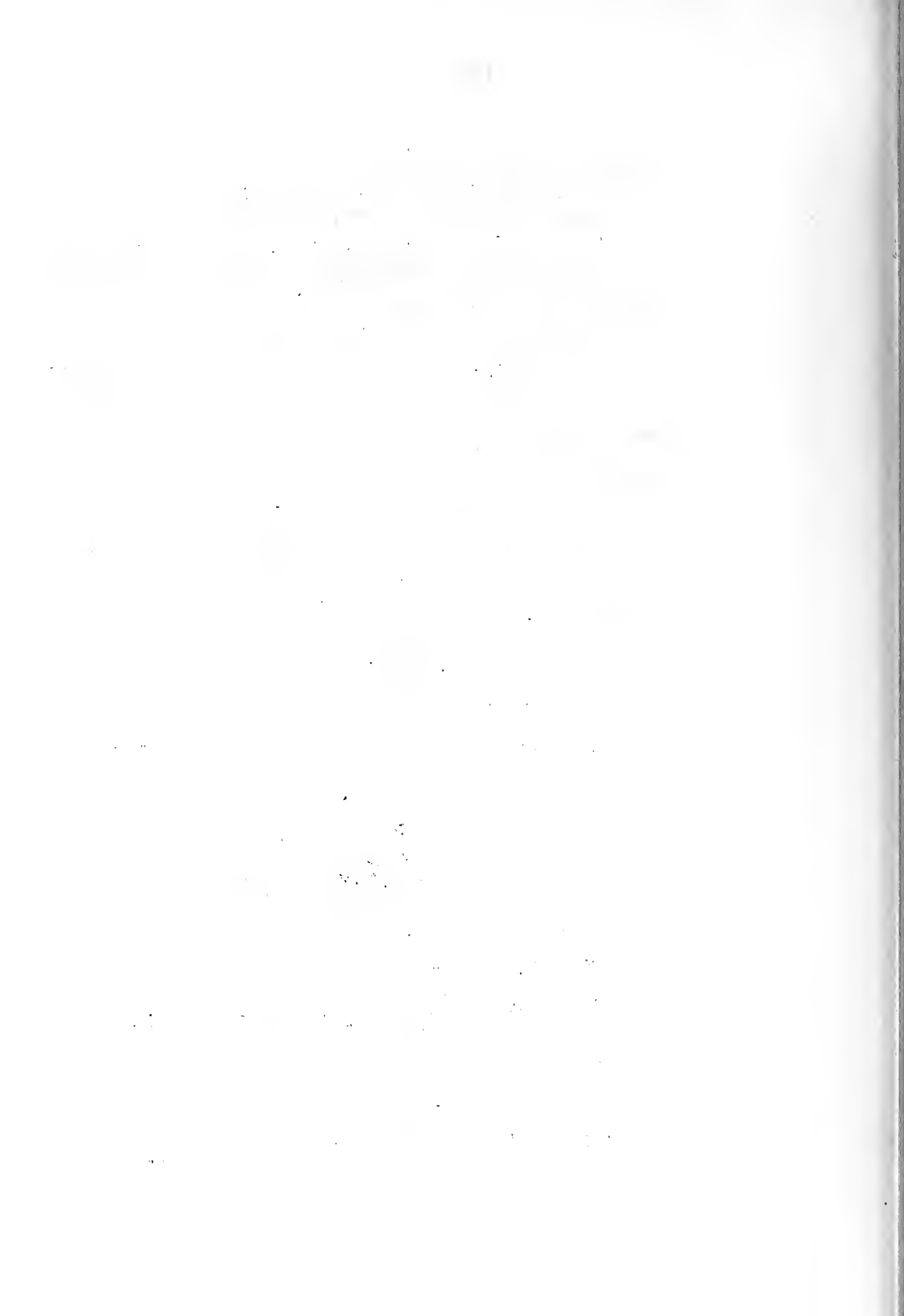
$$26,900 \text{ SFCS} \times \frac{4.5 \text{ hr}}{100 \text{ SFCS}} \times \frac{\$1.775}{\text{hr}} = 2,149.00$$

Structural iron worker labor,

$$84 \text{ beams, } 84 \text{ strands}$$

$$@ 1/2 \text{ hr/strand} @ \$2.525/\text{hr} = 106.00$$

$$\text{Total} \quad \$33,885.00$$



Total = \$33,885.00

On concrete work 27% is allowed for  
overhead and profit and 2% for material  
waste.

$$0.29 \times 33,885 = \underline{9,810.00}$$

Fabrication Total = \$43,695.00

## II. Prestressing Strands

Strand Cost = 48,360.00

On strands 10% is allowed for overhead  
and profit.

$$0.10 \times 48,360 = 4,836.00$$

III. Erection - Labor, equipment rental,  
profit and overhead

$$= \underline{25,000.00}$$

Grand Total = \$121,891.00

## COMPUTATION OF CONVENTIONAL BRIDGE COSTS

The quantities were taken from the design drawings of the bridge. The unit prices are taken from a compilation of contract prices on an identical bridge in the same locality which was contracted for on March 7, 1951.

### I. Concrete for 7" Structural Slab

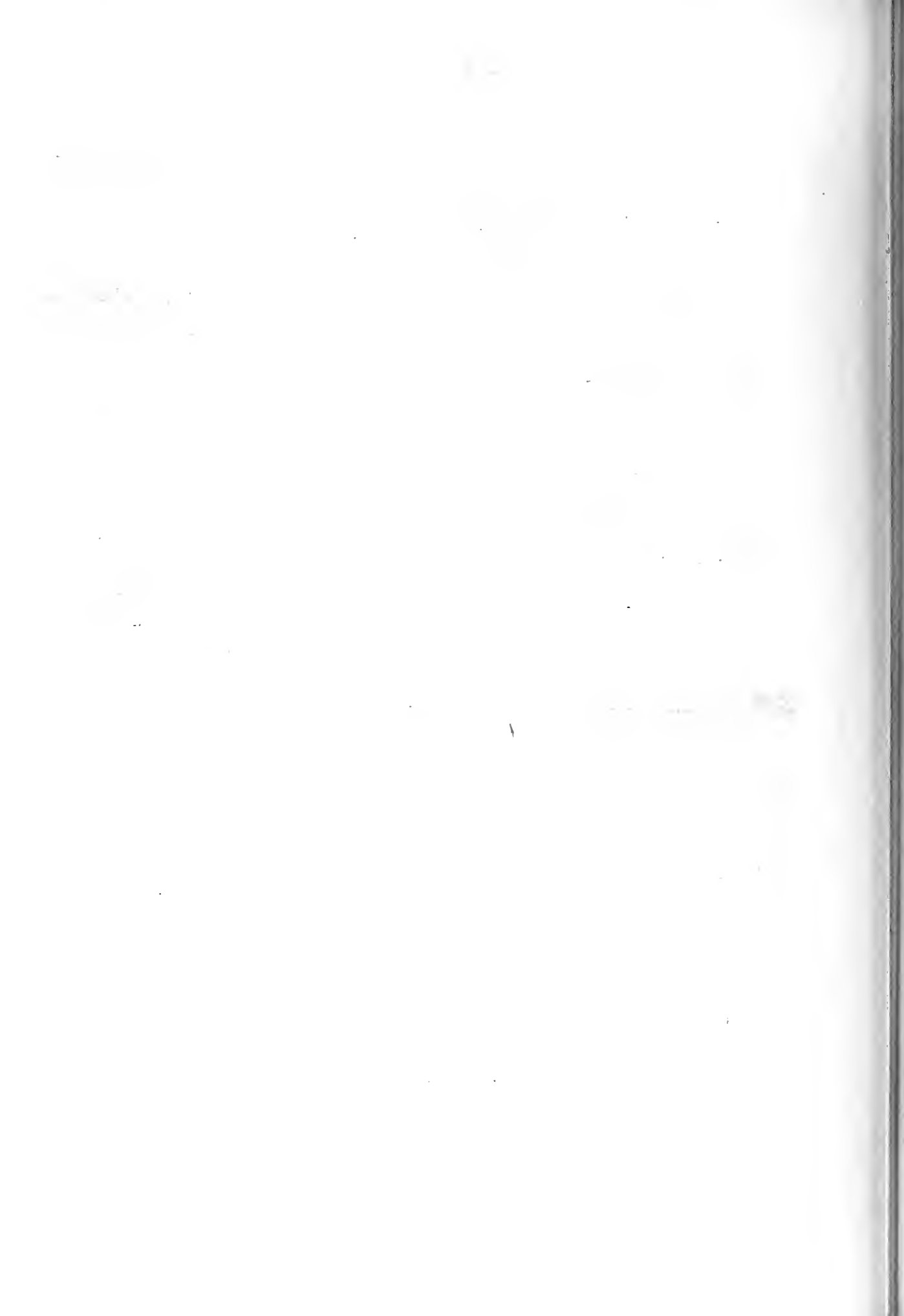
A. 530.2 cu yd @ \$55.00/cu yd \$29,200.00

B. Cement for above

825 Bbl @ \$3.50/Bbl 2,887.00

### II. Conventional Reinforcing Steel

142,082 lb @ \$.13/lb 18,480.00



## III. Spiral Reinforcing Steel

6,370 lb @ \$1.10/lb	\$ 7,010.00
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## IV. Structural Steel

408,000 lb @ \$.16/lb	<u>65,350.00</u>
-----------------------	------------------

	\$122,927.00
--	--------------

2% is allowed for material waste.

0.02 x 122,927	= <u>2,458.00</u>
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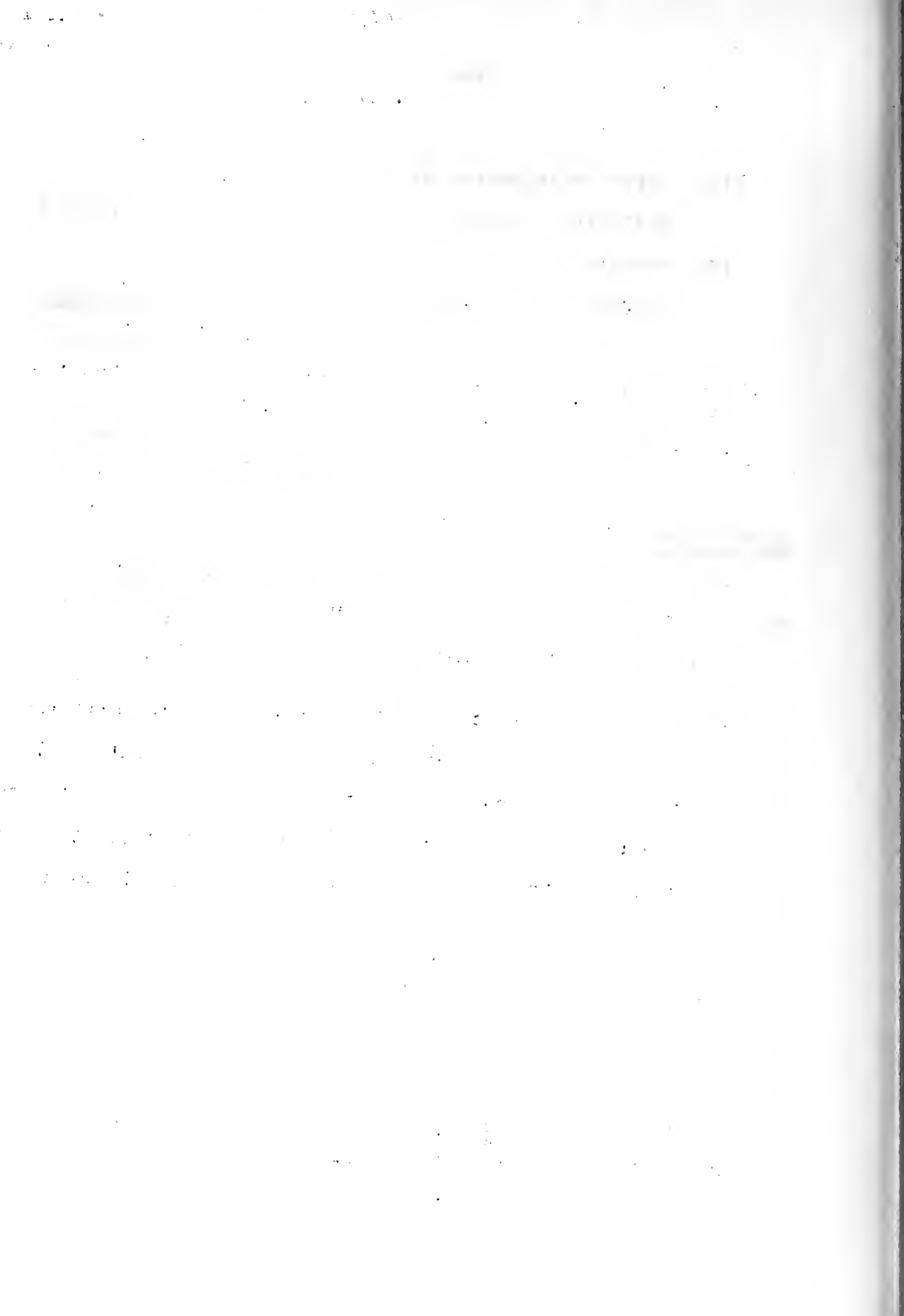
Grand Total =	\$125,385.00
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CONCLUSIONS

The prestressed design shows an economy of \$3,484.00. This is only 2.8% of the cost and, therefore, is not of great significance. The results, however, do show that prestressed construction compares favorably with combined steel and conventional reinforced concrete construction in a large structure.

The prestressed design required 196.4 cubic yards more concrete. It saved 220.3 tons of steel, the conventional bridge using 4.8 times as much steel as the prestressed.

Another factor in this comparison is the difference in construction procedures and the time they require. The prestressed beams can be fabricated at the same time the substructure is being built, and their erection can be started as soon as two adjacent bents are ready for the beams.



Thus it can be reasonably assumed that the prestressed bridge can be constructed in less time. This will convert some of the contractor's overhead expenses into profit, as he will be on the job a shorter period of time.





## PART IV

## FINAL CONCLUSIONS

A comparison of prestressed construction with conventional construction if done element by element does not give a true picture. This is shown by a comparison of the conclusions of Part I with those of Parts II and III. In Part I it was concluded that prestressed beams did not compare favorably in the range of spans 20 to 40 ft with applied loads up to 500 ppf. However, when these beams were incorporated in a structure, certain inherent advantages of prestressed construction, such as more efficient utilization of labor and materials, caused the comparison to change so as to show that prestressed construction was actually as economical as conventional construction when the structure as a whole was considered.

Prestressed construction results in a saving in steel of up to 60% in some cases over conventional reinforced beams. In the combined steel and concrete bridges compared in Parts II and III, prestressed construction replaced the main longitudinal steel sections and all of the conventional reinforcing steel with the small, very high strength prestressing strands. In Part III this resulted in a saving of 79.2% or 220.3 tons of steel. This is a matter of



considerable importance as brought out in the Introduction and should be given serious consideration. Prestressed design utilizes concrete more efficiently than does conventional; thus the considerable saving in steel is not accomplished by using additional concrete.

The trend of construction procedures using prestressed concrete is toward prefabrication as contrasted with in-place construction. This procedure permits fabrication to be done on the ground at a favorable site. This will considerably improve concrete's position in the competition with steel erection time.

It is the authors' opinion that prestressed concrete will become one of the major methods of construction in the future. This will be accomplished when design engineers and contractors become familiar with its many savings and advantages.

The first part of the paper discusses the importance of the study of the history of the United States. It is argued that the study of the history of the United States is essential for a full understanding of the country and its people. The second part of the paper discusses the importance of the study of the history of the world. It is argued that the study of the history of the world is essential for a full understanding of the world and its people. The third part of the paper discusses the importance of the study of the history of the United States and the world. It is argued that the study of the history of the United States and the world is essential for a full understanding of the United States and the world.

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- (9) Letter, E. C. Rodgers, Engineer, Madison County Highway Department, Jackson, Tenn., Mar. 20, 1951, to Mr. George L. Hoffman.
- (10) Letter, Lillie Mai Thompson, Secretary to Mr. Rodgers, Madison County Highway Department, Jackson, Tenn., Mar. 12, 1951, to Mr. George L. Hoffman.
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- (13) Letter, E. C. Rodgers, Engineer, Madison County Highway Department, Jackson, Tenn., Apr. 30, 1951, to Mr. George L. Hoffman.

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(6) Physical and Mental Development of the Child, by D. H. Stoddard, 1910.

(7) Physical and Mental Development of the Child, by D. H. Stoddard, 1910.

(8) Physical and Mental Development of the Child, by D. H. Stoddard, 1910.

(9) Physical and Mental Development of the Child, by D. H. Stoddard, 1910.

(10) Physical and Mental Development of the Child, by D. H. Stoddard, 1910.

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(12) Physical and Mental Development of the Child, by D. H. Stoddard, 1910.

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